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1998 SUMMER STUDY

Joint Operations Superiority in the 21st Century
Integrating Capabilities Underwriting Joint Vision 2010 and Beyond

Volume II
Supporting Reports



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INTRODUCTION

Volume I of the 1998 Summer Study report provided a framework for integrating capabilities underwriting Joint Vision 2010. The task force identified early and continuous application of decisive combat effects, as the central theme of the study, and identified eight supporting and inter-locking operational challenges. These supporting challenges include: assured knowledge superiority, responsive global targeting, exploiting the littoral battlespace, inter- and intra-theater mobility, coalition warfare, force and infrastructure protection, theater ballistic and cruise missile defense, and urban operations. In each of these areas, Volume I describes selected enablers essential to achieving these operational challenges.

Volume II - Supporting Reports contains material that further elaborates on the subjects highlighted in Volume I. Part 1 explores the topic of early and continuous combat effectiveness in further detail, by describing additional enablers that are important elements of this overall capability. Part 1 also contains descriptions of additional enablers for responsive global targeting, exploiting the littoral battlespace, robotics for dismounted troops, and urban operations. Part 2 of this volume provides a summary of related reports describing operational concepts promoted by the military Services that are related to the overall themes of Joint Vision 2010, an overview of recommendations from prior DSB studies that support the findings of the 1998 Summer Study task force, and other supporting analyses conducted by RAND.

PART 1.

Task Force White Papers

CHAPTER 1.

Early and Continuous Combat Effectiveness

CHAPTER 1.

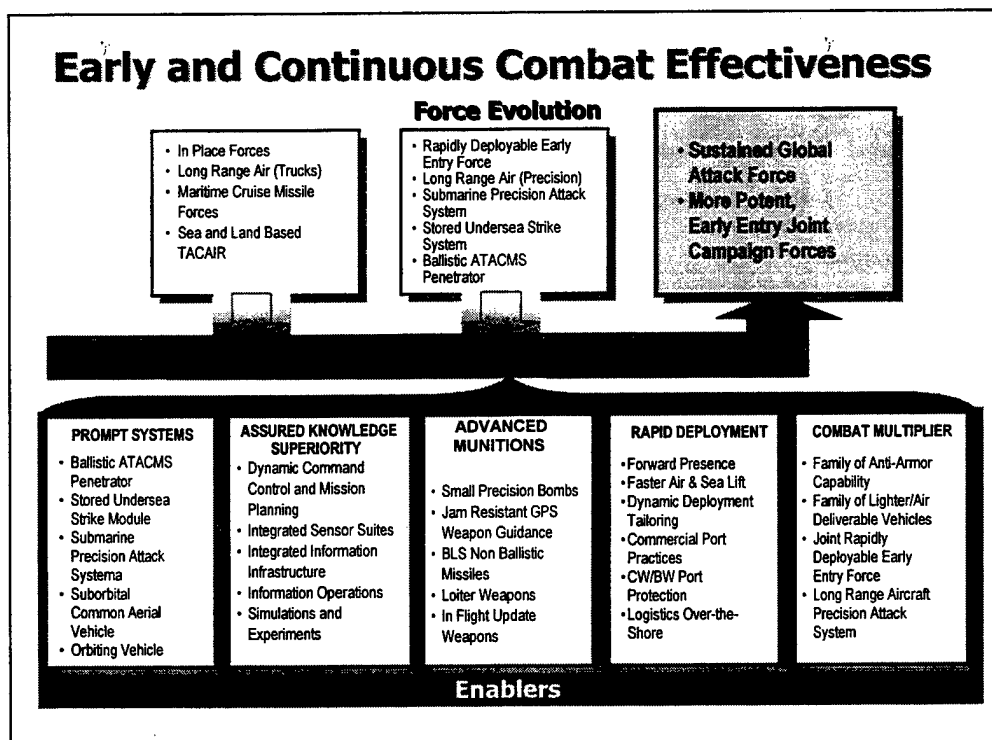
Early and Continuous Combat Effectiveness

Joint Vision 2010's concepts of precision engagement, dominant maneuver, and full-spectrum dominance, enabled by information superiority, grew naturally from the overwhelming tactical dominance achieved by US and coalition forces during the 1991 Persian Gulf War. Bringing precise, focused combat power to bear early in a distant, overseas contingency and providing continuous combat effectiveness is essential to the overarching theme of dominance.

Early and continuous combat effectiveness is characterized by the abilities to:

- Deliver potent military power within hours anywhere in the world;
- Follow-up with more potent operations, including ground forces, within 24 hours; and
- Sustain and augment these forces, including establishing regional operating bases – some being sea based – even when there is limited local infrastructure.

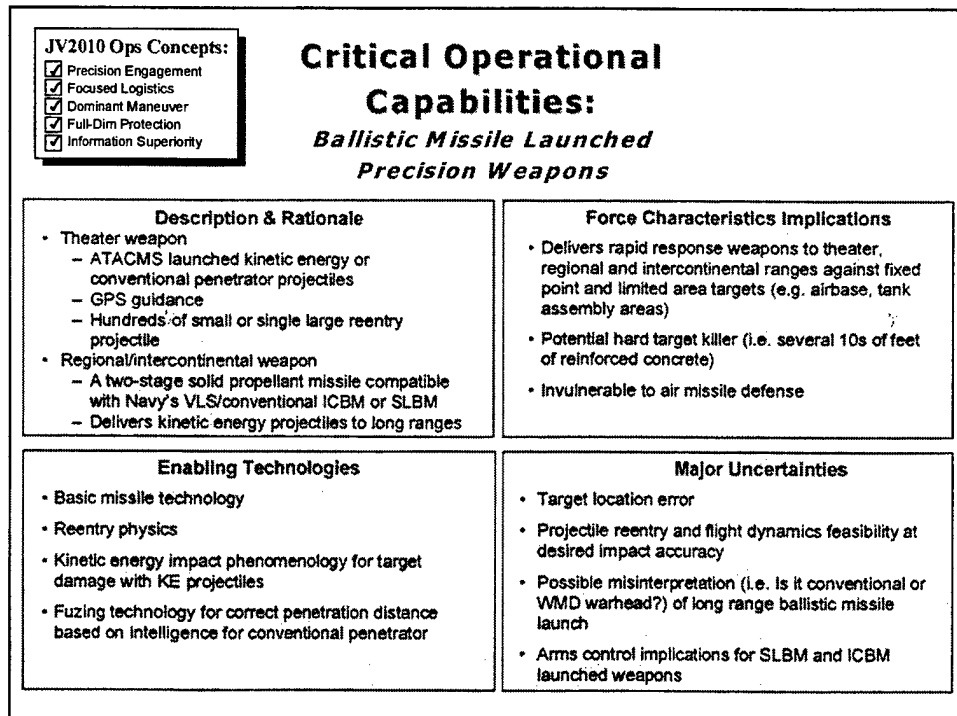
The figure below provides a coherent context for developing forces that can provide early and continuous combat effectiveness. The top of the chart defines expected evolutionary improvements in the operational capabilities of US military forces needed to meet this challenge, with the upper right box defining the goal for 2010 and beyond.



The bottom of the chart shows some necessary enabling capabilities and technologies in five functional areas: prompt systems, assured knowledge superiority, advanced munitions, rapid

deployment, and combat multipliers. These five areas are linked and interdependent. For example, precision engagement by any platform and munition is dependent on knowledge superiority. Prompt systems support rapid early and decisive application of precision force. As Figure 1 shows, the enabling capabilities are many; those highlighted are discussed in Volume I – Joint Rapidly Deployable Early Entry Forces, Long-Range Aircraft Precision Attack System, Submarine Precision Attack System, the Suborbital Space Operations Vehicle and advanced munitions. This chapter focuses on several additional enablers including ballistic missile launched precision weapons, stored undersea strike module, loitering cruise missiles, family of anti-armor capability and family of lighter air deliverable weapons.

BALLISTIC MISSILE LAUNCHED PRECISION WEAPONS



DESCRIPTION AND RATIONALE

An attractive option for attacking high-value fixed point and limited area targets is ballistic missile launched precision weapons using GPS guidance for accurate delivery of kinetic energy or conventional penetrator projectiles. There are several variants of this concept: theater weapons and regional/intercontinental weapons.

The theater weapon variant consists of an ATACMS missile – or ATACMS-like system such as NTACMS fitted with either multiple (>100) short tungsten rods in the warhead or a single conventional penetrator warhead. For the multiple rod warhead, the ATACMS-like missile is launched in a lofted trajectory to provide a high velocity impact. The individual rods are separated from the warhead prior to entry into the atmosphere and the kill mechanism is kinetic

energy impact on the target. Hundreds of rods can be delivered from a single warhead in a pattern appropriate for the target. GPS guidance is used to accurately place the pattern of rods on target. For the conventional penetrator warhead, the ATACMS is launched on a trajectory such that the warhead (e.g. TACMS Block III penetrator with a Navy MK4 reentry body) reenters the atmosphere at a lower velocity to survive reentry but sufficient for excellent hard target kill potential. The warhead is again guided by GPS and uses flap/fins on the afterbody for aerodynamic control in the atmosphere to achieve high accuracy at impact. The payload includes a conventional penetrator warhead consisting of a penetrator case containing high explosive with a smart fuze for accurate warhead detonation at predetermined depths. Also as could carry other conventional munitions for attacking moving or stationary tactical target. These munitions include BAT and LOCAAS among others such as SADARM and newer munitions.

The regional/intercontinental weapon consists of a two-stage solid propellant missile NTACMS (such as surplus C⁴ missiles) compatible with the Navy's Vertical Launch System and capable of delivering a weapon to 2,000 nmi or a conventional ICBM or SLBM capable of intercontinental ranges. The warheads for both missiles could be variants of those described for the theater weapons above.

FORCE CHARACTERISTICS IMPLICATIONS

Ballistic missile launched precision systems could deliver rapid response weapons to theater, regional and intercontinental ranges at any time of the day or night in all weather conditions as long as targeting information is available. The weapons would be effective against fixed point, limited area targets and mobile tactical targets. Area targets could be handled by the multiple rod penetrators and would be effective against such targets as air bases (aircraft shelters and runways), P.O.L. storage sites, fixed radar sites, and tank assembly areas. Tactical mobile targets could be engaged with precision submunitions. The conventional penetrator warhead would be effective against many hard targets (such as those protected by several 10's of feet of reinforced concrete). The systems (particularly ones carrying the multiple rod warheads) would be invulnerable to enemy air defenses and thus provide a capability currently not available with existing systems.

ENABLING TECHNOLOGIES

The enabling technologies are low risk. The launchers use basic missile technology with standard GPS guidance approaches for the warheads. The conventional penetrator warhead delivery vehicle uses existing reentry body designs and the technology is well in hand to achieve the impact velocities and location accuracies required for hard target kills. The long thin rod warhead reentry physics phenomenology has seen limited experimental testing. The Navy performed a hypersonic rod experiment in 1993 flying 3 long (36" - 43"), thin (1" to 1 1/2") tungsten rods on a D-5 warhead station. The missile was flown to a range of 4,000 nmi. Two of the rods used a carbon/carbon nose tip design with a carbon sleeve around the forward portion of the tungsten rod. One rod used a bare tungsten nose tip. One rod clearly impacted the target area at a velocity of approximately 14,000 ft/sec. One clearly failed to impact and the third was uncertain. The one that failed is thought to have been the bare tungsten nose rod as would be expected. Target impact accuracy was not part of this test. These results provide an initial

indication that long thin rods can successfully transit the atmosphere at hypervelocities (velocities > 10,000 ft/sec) and impact the earth. This is an important result for both these concepts as well as the space delivered kinetic energy weapon described later in this report.

Additional tests are required to fully understand the destructive potential of kinetic energy impacting rods on various targets but initial tests look promising. The destruction potential produced by conventional penetrator warheads against certain fixed hard targets is better understood although additional tests are needed to refine current estimates. Advanced fuzing technologies for correct penetration distance based on available intelligence information should also be continued. Trade studies showing the difference in probabilities of kill (due to variations in impact CEP) against certain hard targets using multiple long thin rod kinetic energy impactors or the single conventional penetrator should be performed to identify the most efficient application of each system. Please see Volume III of this report for a more detailed discussion of defeating deeply buried targets.

MAJOR UNCERTAINTIES

The major uncertainties for the kinetic energy rod impactor warhead involves projectile reentry and flight dynamics feasibility at desired impact accuracy. The major uncertainties for the conventional penetrator involve fuze performance, high explosive response, impact accuracy and missile navigation error. All of the systems suffer from the possible misinterpretation of short- and long-range ballistic missile launches – that is, does the warhead contain a conventional or WMD payload? There are also a set of arms control implications for the SLBM and ICBM launched weapons since they strategic launchers would be counted under the current START treaty agreements.

RECOMMENDATION

- Conventional Penetrator Warhead Program: Continue support for existing TACMs Penetrator and precision submunitions such as BAT.
- KE Projectiles: Initiate program to determine the feasibility of reentry and flight dynamics of short and long rod KE penetrators at desired impact accuracies. Increase R&D support for determining KE impact destruction phenomenology on various targets.

RESPONSIBLE AGENCY

- Conventional Penetrator Warhead Program: Departments of the Navy and Army
- KE Projectiles: Reentry and flight dynamics – DAPRA; KE impact phenomenology – DSWA, now integrated into DTRA

COST ESTIMATE

- Conventional Penetrator Warhead Program: See TACMs Penetrator Demonstration Program Plan for details
- KE Projectiles: Reentry and flight dynamics – initiate a \$5-\$10M per year, 3 year program to prove feasibility and determine accuracies. KE impact phenomenology support a \$1-3M per year, 3 year program.

STORED UNDERSEA STRIKE MODULE

<div><div>JV2010 Ops Concepts:<ul style="list-style-type: none"><input checked="" type="checkbox"/> Precision Engagement<input checked="" type="checkbox"/> Focused Logistics<input checked="" type="checkbox"/> Dominant Maneuver<input checked="" type="checkbox"/> Full-Dim Protection<input type="checkbox"/> Information Superiority</div><div><h3>Critical Operational Capabilities:</h3><h4>Stored Undersea Strike Module</h4></div></div>	
<div><h4>Description & Rationale</h4><ul style="list-style-type: none">• Uninhabited underwater missile launch platform (UUMLP) that could be towed to and moored in areas of interest (submerged arsenal ship)• UUMLP's would be towed to forward areas by SSN/SSGN and would be remotely operated• Multiple operational uses</div>	<div><h4>Force Characteristics Implications</h4><ul style="list-style-type: none">• UUMLP's Would Offer an Inexpensive, Covert, and Survivable Early Precision Guided Missile Attack Option in the First Minutes and Hours of a Conflict• Unambiguous Forward Presence and Deterrence Able to Be Placed Prior to or After Achieving Air and Surface Superiority• Support SOF operations</div>
<div><h4>Enabling Technologies</h4><ul style="list-style-type: none">• Command, Control, and Communications• Further Development of "Submarine Oil Tanker" Concept for North Slope Oil• Advanced High Bandwidth Information Superiority Network System</div>	<div><h4>Major Uncertainties</h4><ul style="list-style-type: none">• Funding• OSD & Navy Support• Survivability considerations</div>

UNDERWATER STRIKE MODULE



As the foremost world power, the United States will continue to maintain global interests, and therefore must be able to influence and respond to events with credible military presence and power projection capabilities. In the face of steadily decreasing overseas basing and a shrinking military budget, the United States must maintain the ability, in concert with allies, to execute timely combat operations across the spectrum of potential and actual conflicts. Naval forces sustaining forward presence will be the key to successful introduction as well as early employment of ground forces.

DESCRIPTION AND RATIONALE

Submarine payload modules represent an enhancement to America's existing force of carriers and land attack capable combatants and submarines, not a replacement for these ships or for land-based air forces. Operating under the operational control of the Joint Force Area Commander, submarine payload modules will be capable of supplying substantial firepower, early, giving unified Commanders-in-Chief the capability to halt or deter invasion and, if necessary, enable the build-up of coalition land-based air and ground forces to achieve favorable conflict resolution.

The submarine payload module concept is an outgrowth of the Navy's shift in focus from open-ocean to littoral and addresses current as well as anticipated future requirements for more decisive, responsive, and varied support for the land battle. Leveraging stealth to allow deep penetration of defenses, a wide range of payloads can be placed on the enemy's doorstep in peacetime and in preparation for war. This payload may include tactical strike weapons, vertical gun canisters for Naval Surface Fire Support (NSFS), supplies such as fuel, water, ammunition and food to support a Marine Expeditionary Unit (MEU), an elaborate system of sensors to

monitor the littoral region above and below the waterline, mine warfare systems, and a special operations force (SOF) underwater habitat or command center. These all have the potential to provide the needed "stepping stones" for delivering new forms of military capability "From the Sea."

The strike version of the submarine payload can provide a concentration of massive firepower, which is continuously available and compatible with netted targeting and weapons assignment. However, submarine payload modules, in general, are significant in several ways:

1. Submarine payload modules are delivered and recovered with stealth. This drastically reduces the self-defense requirements of the module. It creates an effective form of tactical deterrence similar to that demonstrated by the SSBN fleet. It also provides the nation's leadership with the option of massing capability without signaling intentions, which could compromise parallel diplomatic efforts. This will provide needed capability without a massive naval force buildup.
2. Manning is not required during deployment. The stealthy submarine payload module is designed for autonomous operation under deployed conditions. The Submarine Payload Module does not require near-continuous defensive coverage of the Aegis combatants. This capability has the potential to de-couple missions, like missiles-in-theater, from the continuous presence of combatants.

EMPLOYMENT

The functional requirements for the submarine payload module stem from a general description of how the module will be employed from "cradle to grave." To provide fidelity in the description of module capabilities and design attributes, the module should be designed as a part of a system, supporting all phases of operation, from pre-positioning like the Maritime Pre-position Forces (MPF), to refurbishment after deployment, or even to self-destruction, should the mission be compromised.

Pre-Position. The submarine payload modules assigned to each theater of operation will be pre-positioned to ports such as Rota, Spain, Diego Garcia, and Guam. This is necessary to reduce the deployment times. Routinely moving the modules from site to site, and to and from sea, enhances the deterrent affect of the modules by creating uncertainty about the location of the modules and their advertised capability to deliver payload from a stealthy posture, much like an SSN or SSBN. These strategically deployed payload modules can provide theater commanders with significant firepower from a stealthy launch platform. About a dozen modules would provide three modules in each of the Atlantic, Indian Ocean, and Pacific regions and several modules in CONUS for use in training and tactical development exercises.

At pre-position sites, whether pierside or at anchorage, the modules can be maintained ready for operation. For re-configurable modules, final loadout of the mission canisters can be carried out by overhead crane. The payload canisters can be sized to allow rapid airlift to the pre-position sites should last minute modifications to the submarine payload module loadout be required.

By design, sensitive sensors, such as radio antennas and acoustic transducers, as well as mechanical equipment, such as the tow cable and anchor handling systems, are accessible from topside for maintenance. The modules can be easily dry-docked for hull cleaning. A small

integrated logistics support (ILS) crew is assigned responsibility for the long-term care of the modules.

The payload modules will require very little maintenance when pre-positioned. With the exception of periodic hull cleaning which will require dry-docking, no routine maintenance will require the module to be removed from the pre-position site. As a result, the submarine payload module will be able to remain pre-positioned virtually indefinitely, effectively limited by the shelf life of the payload itself and on-board power.

Activation. When the submarine payload modules are called into service, or activated, from the pre-position sites, very little remains to be done to make the module seaworthy. Shore services are removed (if required), fuel tanks are topped off, system checks are completed, and the module is maneuvered to the channel by tugboat to meet with the awaiting SSN. This whole operation can be streamlined to take only several hours. By far, the transit time for the host submarine, and the delivery time for the special canisters if they must be flown in, drives the turnaround time for activating a pre-positioned payload module. To accommodate operator flexibility, the steps necessary to prepare the module for tow should take less than 12 hours.

Delivery. Once mated with the host submarine, the submarine payload module is delivered to the area of operation at speeds of roughly 10 knots. In the North Atlantic Ocean, including the Mediterranean Sea, for example, this means that the module can be delivered to the coast of Norway, or to the shores of Syria, in a week, to a week and a half from Rota, Spain. By comparison, deploying straight from CONUS, say Norfolk, adds one to two weeks to the net delivery time. This provides a strong justification for maintaining the modules at pre-position sites. To provide a rough estimate of the delivery time to the northern coast of South America, from either Rota, Spain, or Norfolk, Virginia, it takes about two weeks to deliver a payload module to Cape Sao Roque, at the easternmost point of Brazil.

Diego Garcia provides a logical pre-position site for the Indian Ocean theater of operations, including the Persian Gulf region. From Diego Garcia, a module can be delivered to either the Straits of Hormuz, or to Jakarta, Indonesia, in about a week and a half. It takes about two weeks to deliver a module to the tip of Africa. To maintain stealth, and therefore avoiding the Suez Canal, it would take more than a month to deliver a submarine payload module to this part of the world from CONUS.

Guam provides a logical pre-position site for the western Pacific Ocean theater of operations. From Guam, a module can be delivered to locations ranging from the Yellow Sea to Jakarta, Indonesia, in less than two weeks. Deploying modules from Hawaii adds about two weeks to the Guam-based delivery times. Deploying from San Diego adds another week or two.

Drop-Off. Once the host submarine arrives at the deployment site, the module must be dropped-off. This involves several more specific steps. First, the exact site for module drop-off may require precision navigation, possibly involving bottom-contour navigation, in order to locate a suitable landing zone for the module. Detailed landing zones can also be located and mapped by SSNs in the normal course of peacetime operations. Next, the module is released from the host submarine and either bottoms, anchors, or both, at the landing zone. Next, the module communications systems must be actuated. This may involve activating acoustic transmit and receiver capabilities and other sensors. Before the host submarine leaves the area, status checks may be performed to test the module. Finally, once all preparations have been completed, the module may be powered-down to a "sleep" mode. This will enhance the endurance of the

module, and reduce its radiated signature while deployed. As a design goal, the module, as conceived, should be designed to "sleep" for three to twelve months. These actions are estimated to take 12 hours after the SSN and the module arrive at the landing zone. Once the module has been powered-down to "sleep" mode, the SSN may depart the area, no longer hindered by the towing operation, to support other tasking.

The deployed modules will fall under the tactical control of the battle group as part of the joint force. Although the module is clearly a submarine asset during delivery phase of operations, the surface fleet is better able to watch over the module once it is dropped off. Ships, submarines, and aircraft in the general area will be cognizant of the location of the module and will provide loose "coverage" to monitor its "health" and status. For example, once a week, Maritime Patrol Aircraft (MPA) could query the module using specific sonobouys, to ascertain system status. In any case, no single platform will be "tethered" to the module. Assets chopping into and out of a theater of operation can routinely turn over responsibility for the deployed submarine payload module.

"Wake-Up." The payload module is "awakened" using a "bell-ringer" message such as an ELF radio message, or an acoustic signal. The "wake-up" message starts the process of energizing payload launch systems and the weapons themselves, activating power systems, and command and control.

For the strike module, targeting data may be updated at this time, although it is preferable to deploy the module with a preset library of target packages, which are kept up-to-date routinely. The targeting message, in this case, is limited to defining a salvo where missiles are assigned to target packages.

Currently, based on the Tomahawk missile design, this "wake-up" cycle time will be dictated by the time that it takes to "spin-up" the missiles. If a version of the Standard Missile is employed, spin-up time is very short. Therefore, the power demands of missile "spin-up" using air-independent power sources must be factored into the design.

Launch. The submarine payload module can launch its payload with virtually no warning, and quickly return to a stealthy posture once a salvo is away. Furthermore, the battle group assets, namely the Aegis ships, have not had to protect the strike asset for the weeks and months leading up to hostilities.

Certainly air coverage from nearby Aegis Ships at time of launch provides added survivability, but is not a requirement. The module's primary mode of self-defense is its stealth while awaiting a launch signal, and the ability to rapidly return to a stealthy mode after the missiles have been fired. In terms of detectability when launching missiles, the submarine payload module is similar to an SSN. Based on feedback from fleet exercises, even given our advanced capability, it is very difficult to ascertain the location of the SSN launching missiles unless a platform happens to witness the launch first-hand.

Return to Stealth. Once a salvo is launched, the payload module may be quickly returned to a stealthy posture. Before returning to complete "sleep" mode, it may be necessary to recharge batteries. Once submerged, the module returns to anchorage or the bottom.

As a goal, the strike module is designed for 10 firing cycles. This drives the power management features of the module.

In any case, the module should be designed to be flexible enough to allow the operators to tailor the operations based on the threat.

Recovery. Regardless of whether or not the submarine payload module has been used to launch weapons, it is desirable to recover the module with complete stealth. The host ship must be capable of recovering the tow cable, without the use of divers.

Recovering the module covertly offers many advantages. The foremost may be the ability to recover expensive hardware, especially if it has not been used. This capability also offers the nation's leadership an option to recover assets that were deployed, unbeknownst to the potential enemy, as a parallel contingency to ongoing diplomatic efforts. If the enemy were to find out that the modules were deployed, this could interfere with future missions. The mere ability to deploy and recover the modules covertly will become a powerful deterrent tool, whether or not the modules are actually on station, much like the deployment of SSBNs.

Flexible Payloads. The flexible canister payload module supports mission ranging from logistics delivery to advanced warfare. These systems may not need the same module-based power and connectivity features as the strike module. But they will retain the need for basic functions allowing the module to be towed, maneuver to and from the surface, and, in general, "launch" the payload. Logistics missions could be carried out using smaller versions of the larger payload module where flexible load-outs of payload canisters can be loaded in each payload tube. Advanced warfare missions could use the same flexible payload module as the logistics mission, employing payload canisters containing advanced sensors or SOF command bunkers, for example – any advanced mission package that will fit inside a standard-sized payload tube.

If the canisters are dropped-off individually, the payload module will have the capability to release the smaller canisters either by dropping or floating out of the overall module "truck." The empty "truck" can be reused or left nearby for potential recovery of the smaller canisters. In the case of the advanced warfare missions, the module can act as the central power, processing, and communications system for a distributed array of smaller payload canisters, perhaps strung together with fiber-optic cable.

Logistics Module. The logistics module is very similar to the strike module in outward appearance, but with fewer payload tubes. Instead of missiles in each payload tube, fuel tanks, or canisters of fuel, water and supplies are made available. Supply canisters may be mixed with vertical gun canisters for NSFS to produce the idea package for the MEU, for example.

The US Marine Corps concept for projection of power ashore is known as Operational Maneuver from the Sea or OMFTS. In order to reduce the risk to the assault force, it calls for movement from ships at sea directly to objectives inland without stopping to establish a beachhead. Some elements of OMFTS represent dramatic departures from previous Marine Corps doctrines with respect to logistics and fire support. This concept entails the debarkation of troops from distances in excess of 25 miles to provide sufficient safety to the ARG. After debarkation, it is envisioned that the ARG will return to a safe haven located up to 100 miles at sea. Due to the standoff distances required, it is expected that re-supply will be accomplished by tilt rotor and conventional helicopters.

The flexibility and near shore support provided by a submarine payload module may lessen some the problems associated with sea based support, without unnecessarily putting sailors in harms way. The Marine Force Support (MFS) Module includes sufficient fuel, water,

ammunition, and food storage to support a complete MEU for a period in excess of ten days. This estimate is based on a technical paper published by the Naval War College entitled "The Logistics Implications of Operational Maneuver from the Sea" and involves the re-supply of a highly mobile MEU Special Operations Command (MEU (SOC)). The Ground Combat Element (GCE) being re-supplied is comprised of approximately 277 marines and their assault vehicles (AAAVs and HMMWVs). The module also includes an organic NSFS capability that can be controlled by either Joint Force Command, JSTARS aircraft or directly controlled by the forces ashore.

The Concept of Operations for the Large MFS Module begins with a decision to send assault forces ashore. After the battlespace has been sufficiently surveyed, a submarine will covertly deploy the MFS Module at a pre-established location. The module will follow an identical operation as the strike module for deployment. Once bottomed, the MFS Module could release a communication buoy to allow re-supply helicopters and tilt-rotor aircraft to locate it and command its supply operations.

Immediately following bottoming, the module will enter a sleep mode as in the strike mission, until called on by the re-supply aircraft. Once called on, the module will deploy the log payloads in the tubes to float on the surface. Fuel and water will be stored in existing design 800-gallon bladders within a pair of payload tubes.

Advanced Warfare Module. Advanced warfare operations includes the category of missions where sophisticated arrays of sensors are deployed from a canister and dropped off by a submarine payload module. The arrays of sensors may include acoustic, radio frequency, and visual sensors distributed over a wide area of operations. Advanced warfare missions may also include defensive and offensive mining. Mine fields may be found, mapped, monitored, and cleared by remotely operated vehicles operated from a central base contained in a drop-off canister. Other canisters may deliver mines into a harbor, when activated. Special Operations Forces, particularly SEALs, may be able to operate from submerged bases where the ASDS may be docked and recharged. This may provide an extended combat radius for ASDS or provide a sortie point for the ASDS awaiting the return of the host SSN called away to conduct another mission.

The Benefit of a Mini-Sub Unmanned Underwater Vehicle (UUV) Adjunct. While not part of the baseline system design, a mini-sub adjunct provides a utility vehicle to support many other missions. It may also be a payload, in and of itself. A mini-sub adjunct can deposit sensors, collect intelligence, insert SOF personnel, conduct Mine Warfare missions, and possibly even conduct limited endurance ASW.

As a utility vehicle, the mini-sub can provide a set of "eyes" and "hands" to assist with large module deployment and recovery, module maintenance, and networked sensor maintenance. When distributing acoustic sensors, for example, the module can drag the sensor to the ideal location. It can also repair communication cables attaching canisters to each other or to the larger module or even to shore.

As a payload delivery vehicle by itself, the mini-sub could be designed with enough rechargeable propulsion to carry out very specialized missions using re-configurable ("bolt-on") payload systems. One, or several, mini-sub could carry out a range of advanced missions sustained by a host SSN.

ENABLING TECHNOLOGIES

Module Design Depth Capability. The design submergence depth for the payload module is a function of the requirements to provide a safe and flexible towing evolution for the module and the host ship, and to enable the module to be deployed in littoral waters over the continental shelf. From a towing perspective, deeper is better since a larger towing depth range allows the module to avoid near-surface sea-state and flow effects, provides for normal and emergency depth excursions of the module, and minimizes restrictions on the host ship's operating range for normal and emergency depth and navigational maneuvers. A deeper design also allows more flexibility in deploying the module, including insertion and extraction of the module by a host ship. On the other hand, increasing the design depth will, in general, increase the cost of the module features controlled by submergence effects, primarily the pressure hull structure and penetrations.

A design depth of greater than 400 feet has been determined to provide adequate flexibility for safely towing the module. This depth is also considered more than adequate to allow deployment of the module anywhere in continental shelf waters, where depths will typically be less than 600 feet. Regarding module costs, the design depth still provides for a relatively cost-effective structural design, since at this depth, the pressure hull structure design is generally stability-limited, rather than stress-limited. This means that lower-cost steels, like HSS, could be used with minor weight penalty (compared to HY-100, for example). Alternatively, lower strength, non-magnetic, corrosion-resistant steels could also be used without incurring unmanageable structural weight effects.

To ensure safe towing of the payload module, the recommended submerged design test depth is >400 feet, based on considerations for the host ship and the payload module. During towing the module should always be maintained at a certain minimum depth to prevent detection of the module while submerged by visual, magnetic, wake, or other means, and to avoid sea state effects and near-surface forces, which could jeopardize the safety of the tow or actually cause the module to broach the surface. The minimum recommended depth is 250 feet, which is controlled by worst-case, large-amplitude waves in the Pacific Ocean.

The host ship during tow should be deep enough to avoid propeller cavitation effects. Considering the powering requirements for towing a large module at about 10 knots, a minimum ship depth of about 200 feet is required. Since the host ship would be deeper than the module during tow, this requirement would be met by keeping the minimum module depth at 250 feet, as recommended above.

Besides the minimum depth limit, an additional depth range below the normal operating tow envelope must be provided to allow for depth excursions due to an operational malfunction or casualty condition, such as a control surface jam, and to provide adequate operating envelope for the host ship to execute evasive maneuvers. A range of about 150 feet below the normal tow envelope is considered adequate for this purpose.

After providing for the minimum below-surface depth (250 feet) and the emergency excursion envelope (150 feet), the remaining depth range is the normal operating tow envelope. For a >400-foot design depth, this normal envelope would be 200 feet, which would allow for depth variations due to salinity and density gradients and normal ship navigational maneuvers.

The continental shelf, is commonly defined as the shallow water, immediately adjacent to land, with a relatively shallow slope. The Continental Shelf ends at a demarcation with the Continental Slope where water depth starts to fall off more rapidly. Worldwide, the average depth of the deep extremity of the Continental Shelf is 200 meters.

As a tradeoff consideration when deciding design depth for the payload module, doubling the design depth from 50 fathoms to 100 fathoms, for example, results in a 60 percent increase in the area available to deploy the module on the bottom. Therefore, a >400-foot design depth is preferable for operational flexibility.

Stealthy (Submerged) Recovery. The stealthy recovery of the submarine payload module with an SSN increases the flexibility of the mission, projects a non-aggressive posture, and provides for the safe withdrawal. It allows for the periodic repositioning of the module between several sites to enhance module security. Stealthy recovery allows the capability to be withdrawn with a low probability of detection. Stealthy recovery minimizes exposure to retaliation or adverse weather conditions. The evolution of preparing for a submerged tow could be done cautiously and meticulously under the security of stealth. The process would provide adequate time to survey the module for obstructions or possible sabotage and take corrective action.

Given the overriding precept of this submarine payload module concept to provide additional payload capability without taxing existing combatant forces, the stealthy (submerged) recovery is worth retaining as a baseline capability.

Autonomous Versus Manned Operation. Several key issues arise when considering whether or not to deploy unmanned, autonomous modules capable of delivering massive amounts of firepower. These issues are self-defense, connectivity, and compromise.

For the submarine payload module, stealth will reduce, but not eliminate this burden on the rest of the battle group. It is likely that the module will receive general supervision by platforms of opportunity, but with significantly less burden on the manned combatants.

The connectivity issue affecting a submarine module will be addressed with continuous, "bell-ringer" communications. It may be desirable to conduct routine "health" queries to demonstrate end-to-end connectivity. Once the "bell-ringer" message is received, redundant and more robust communication systems can be deployed.

Module Compromise. Potential compromise of the submarine payload module perhaps raises the most significant concerns. What happens if the unseen module stops responding to a "health" query? Or unfriendly forces are investigating the area where the module was deployed? The standard submarine payload module can easily be designed with tamper detection systems and programmable responses ranging from sending a "help" message to self-destruction. Command destruction, from any platform, can also be a design feature. The response time of the self-destruct signal can easily be very short, measured in seconds or minutes. However, self-destruct capability raises more specific concerns: Does the capability to self-destruct require a new rule-of-engagement? The module becomes an automatic, or remotely activated mine of considerable size. It may be difficult to differentiate between military salvage operations and innocent fishing activity without a nearby platform.

Destroying a module will create a localized ecological problem due to the quantity of hazardous materials, particularly in the weapons and fuel supplies, and due to the proximity of the module to shore.

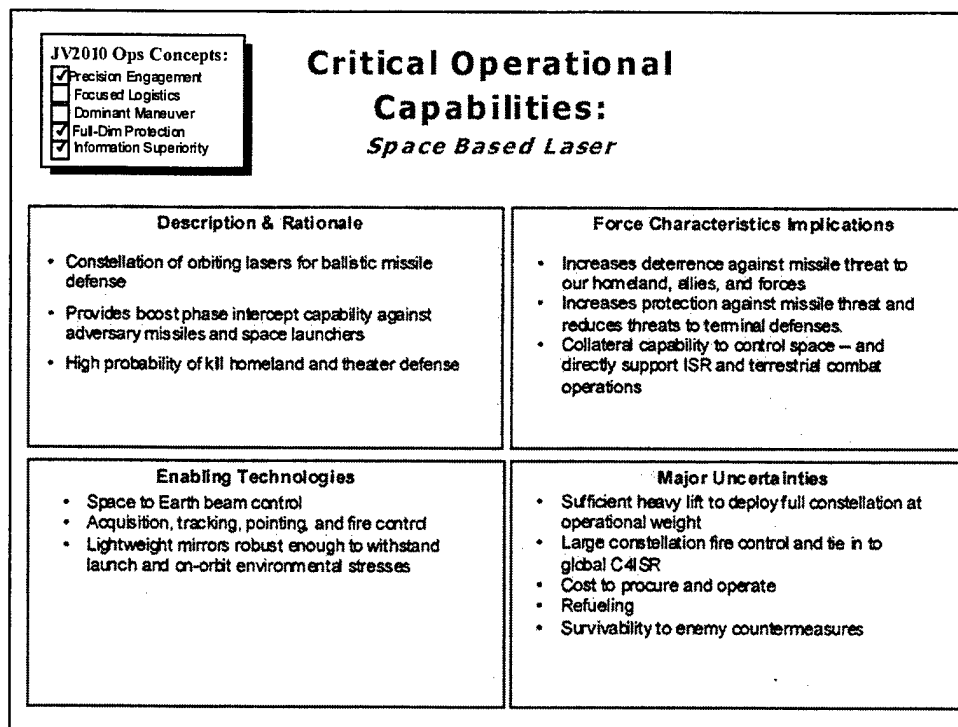
In the final analysis, self-destruct capability may be untenable. A less devastating scuttling method may be preferable – flooding down the module to thwart salvage operations. Or simply accepting a certain degree of risk and the ensuing need to provide some defensive coverage for the deployed module. Nevertheless, if the module is compromised, is in the process of being recovered by an enemy, or has been turned against friendly forces, a reliable scuttling or self-destruct capability will have significant tactical importance.

SUMMARY

In summary, the submarine payload module can serve as a force multiplier to allow the Navy to stretch shrinking resources across the gamut of less capable threats. Submarine payload modules can be deployed from pre-position sites like the Maritime Pre-position Force (MPF) ships. During routine deployments, a module may be kept in theater under the tactical control of the battlegroup. During crises, it will be nearby to deliver precisely the right payload, and in sufficient quantities, to significantly influence the land battle “From the Sea” toward a successful outcome. In the interim between routine deployments and an all out crisis, the unseen potential of the submarine payload module will create a new form of tactical deterrence.

The Summer Study task force recommends that the Department consider developing the Underwater Strike Module.

SPACE BASED LASER



The Space Based Laser (SBL) would provide the nation with a highly effective, continuous coverage boost phase intercept option for both theater and national missile defense. The SBL platform would intercept ballistic missiles by focusing and maintaining a high powered laser on the ballistic missile until it achieved catastrophic destruction. Energy for the sustained laser firing would be generated by the chemical reaction of hydrogen fluoride molecules.

The boost phase intercept capability of the SBL would provide:

- Defense against advanced submissions; and especially CW/BW payloads.
- An additional tier for leakage reduction;
- Deterrence against the use of WMD payloads through the threat of launch-country impact of debris;
- Defense against multiple threat regions simultaneously;
- Mitigation of the problem of falling debris from terminal intercepts; and
- Defense against submarine launches.

A constellation of a sufficient number of SBLs could provide global coverage and could defend against hostile space launches as well as missiles. This level of space superiority and security against ballistic missile attack is likely to deter potential adversaries from attempts to challenge the United States through ballistic missile attacks or through attempts to use space in wartime to conduct intelligence, surveillance, and reconnaissance (ISR) or other operations in wartime.

The SBL could also make contributions to other missions such as space and air superiority, precision engagement, and information dominance. It might be able to engage threatening LEO satellites or aircraft, illuminate terrestrial targets for precision engagement, and gather information from spaceborne, airborne, and surface objects. When tied into a global ISR system, the SBL constellation could rapidly and flexibly collect information on targets, defend itself, defend friendly territory from ballistic missile attack, and then support precision attacks on the adversary.

At some wavelengths, the SBL may be able to also target low altitude aircraft as well as thin-skinned structures and vehicles on the ground. This could give the SBL the capability to conduct the offensive and defensive counterair or ballistic missile attack operations (i.e. "Scud hunting") missions.

As with any on-orbit force application system, the distance from logistic support could become a liability in wartime. Since the SBL operates using chemical consumables, it would require on-orbit replenishment and resupply — especially after large scale or lengthy engagements. The tradeoffs between cost, lift availability, number of threat systems, and fuel would therefore have to be balanced carefully with the size of the constellation required to defend against the projected threat.

TETHERED AERIAL OBSERVATION

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>Tethered Aerial Observation</i>	
Description & Rationale <ul style="list-style-type: none"> • Robotic Helicopter, or Other Technology Geographically Tied to Small Unit by RF or Physical Connection • Provides Several Dozen Meter Elevation for Sensing, Jamming, SEAD, Fire Support, Direct Attack for Local/Distributed SR • Powered by Small Vehicle Electrical System • Dual Mode Sensors for Flexibility and Redundancy • Operated by One Person From Equivalent of Pick up Truck Flatbed 	Force Characteristics Implications <ul style="list-style-type: none"> • Capability to Survey the Local Battlespace for Small Units • Elevation Provides Ability to "Look Over the Next Hill" for Surveillance and Reconnaissance—especially Useful in Complex or Urban Terrain • Provides Real-time Local Battlespace Information to enhanced local situation understanding 	
Enabling Technologies <ul style="list-style-type: none"> • Flight Control Software for Unmanned Station Keeping • Advanced Survivable LO Helicopters or Other Technology • Integration of Remote Platforms With IUSS and III Global C4ISR Network 	Major Uncertainties <ul style="list-style-type: none"> • Survivability • Sufficient Information Provided to Provide Value Added to Global C4ISR • Cost 	

Even with continuous real time global surveillance, combat forces on the ground will still need the ability to "see over the next hill" without reliance on limited ISR assets. Small, locally controlled sensors with the vantage point provided by elevation could provide useful real time information to soldiers, Marines, and Special Operators – especially in complex or urban terrain. Non-organic UAVs, fixed wing and satellite assets may not provide the type and fidelity of data that the forces needs in such circumstances.

UAV operational concepts should not make "situational understanding" a 2-way street with the enemy. This can be averted by giving the forces an elevated view. Masts are already in use on some armored fighting vehicles – but this is an unworkable solution for dismounted infantry.

Another possibility is a helium balloon that can be inflated and unreeled aloft to an even greater height such as 100-200 feet. This would be a tethered-UAV like configuration that stayed over friendly territory. Against an unsophisticated enemy, this could reduce the signature of the observation platform enough so as not to alert him to our reconnaissance efforts, while at the same time providing units with the ability to see "over the next hill". This would be a modern, low-technology version of the observation balloon used in WWI to adjust artillery fire into the trenches. Unfortunately, balloons are extremely vulnerable and subject to adverse environmental conditions. Powered solutions such as small uninhabited helicopters and the ducted-fan vertical-take-off-and-landing unmanned air vehicles being tested at the Naval Space and Warfare Center may be more survivable and could carry heavier sensor (and perhaps weapon) payloads.

The platform should be low observable – to minimize the signature of both the platform and the supported unit, and it should have long endurance to maintain the continuous real time situational awareness that the unit needs.

The tether might or might not be physical – it could be an RF link. To keep radio traffic to a minimum, most sensor processing would be performed by the remote payload. Acoustic and visual motion detection would detect, identify, and locate targets of interest. Preprogrammed responses would be activated upon detection and, depending on the threat, might include simply an alert to the operator, an automatic transfer of a static image, a laser range readout or an image stream.

For ease of use and system affordability, the operator's control and display interface should be a laptop computer running a Windows-type graphical user interface. All commands to the remote sensors would be initiated using a standard keyboard and pointing device – or voice command and/or hand signals when voice and visual recognition software is unavailable. All data and images sent back would be displayed on the laptop's color monitor. Communication between all remote payload subsystems and the control/display station would be very "Internet like" – with the same graphical front end as the worldwide Global Integrated Information Infrastructure Network (from which national, theater, and parent unit information would also be available).

RECOMMENDATION

Move from technology program to Milestone 0. Fully fund – ensuring compatibility with DoD-wide C4ISR systems.

AGENCIES RESPONSIBLE

US Army Systems Command, USMC Systems Command, Naval Space and Warfare Center

COST

\$Tens of Millions (similar technologies are already flying)

JV2010 Ops Concepts:

- ☐ Precision Engagement
- ☐ Focused Logistics
- ☐ Dominant Maneuver
- ☒ Full-Dim Protection
- ☒ Information Superiority

Critical Operational Capabilities: *On Demand Sustainment*

Description & Rationale

- Prepackaged Sustainment Air-delivered Directly to Small and/or Dispersed Units
- Eliminate the Large Logistics Footprint
- Enables Sustainment Bases to Be Located in Benign Areas or Off-shore (Seabased)
– All Classes of Supply
- Not Dependent on Roads or Traditional Lines of Communication/Delivery
- Autonomous Systems—minimize Aircraft Loss

Force Characteristics Implications

- Allows Forces to Maneuver Without Burden of Logistics Trains
- Lighter More Agile Combat Teams
- Affords Protection to Logistics Personnel/Logistics
- Supply from the sea

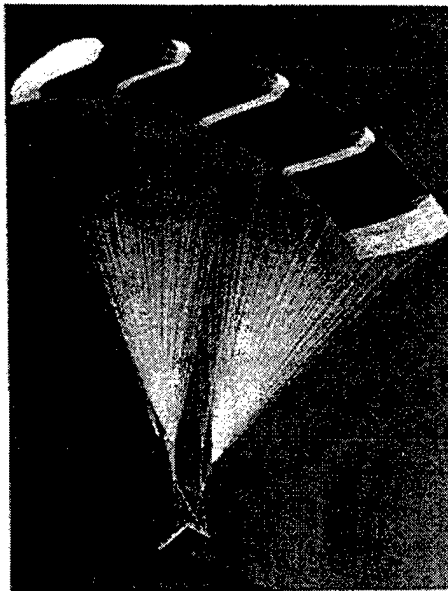
Enabling Technologies

- Agile, Precise, Unmanned GPS Guided and Steerable Parafalls Delivered From Loitering Theater and Strategic Airlift
- Unmanned Aerial Vehicles (UAVs)
- Bulk Liquid (Water, Fuel) Containers and Distribution Systems Adapted for GPS and/or UAV Delivery
- Selective Off-Load/Selective Packaging Technology

Major Uncertainties

- Technology Risks
- Size/Practicality of New Energy Sources
- Cost
- Operational feasibility

Sample Technology for On Demand Sustainment



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DESCRIPTION AND RATIONALE

Technologies for on-demand sustainment would be for a system to provide precision aerial resupply from a variety of fixed or rotary wing aircraft and/or unmanned aerial vehicles (UAVs) at standoff distance that allows the aircraft/UAVs to operate without being exposed to hostile fire. This capability will significantly reduce the traditional buildup of logistics/sustainment in close proximity to combat units in order to provide responsive resupply. Delivering the required sustainment from offshore platforms and/or bases in benign areas can reduce the large logistics footprint – as well as the associated force and asset protection requirements. Moreover, military units would not be required to maintain and guard the traditional lines of communications (resupply routes on roads) currently used to move logistics.

FORCE CHARACTERISTICS IMPLICATIONS

Delivery of resupply via parafoil or UAV reduces the requirement for large and cumbersome logistics trains that move with maneuver forces. Therefore, combat teams can become lighter and more agile, significantly improving mobility and lethality while reducing size. Because the size of logistics formations moving with the combat formations is reduced, the risk and force protection requirements are also lower.

ENABLING TECHNOLOGIES

A cargo aerial delivery system that reduces the reliance on manned aircraft is required. Specifically, a family of agile, precise, unmanned aerial delivery platforms that are simple to operate and maintain offers this enabling technology. Recommended technologies to explore include:

1. Guided Parafoil Aerial Delivery System (GPAD) to provide standoff release aerial delivery by a GPS-guided system for resupply
 - 100 meter delivery accuracy
 - Various sizes – up to 10,000 pound payload capacity for largest size
 - 20-50 kilometer standoff distance minimum
 - Capable of being dropped from altitudes of up to 25,000 feet AGL
 - Capable of being delivered from all cargo carrying fixed and rotary wing aircraft
 - Powered parafoil with ten hour loiter time capable of landing on unimproved surfaces
2. Unmanned Aerial Vehicle—Logistics Variant (UAV-LV)
 - Drone helicopter.
 - Fixed-wing UAV with cargo (2000 pound plus) capability that can either deliver cargo loads by parachute or land and offload cargo.
 - Extended loiter times.

3. Bulk liquid (water, fuel) containers and distribution systems adapted for GPAD and/or UAV delivery.
4. Selective off-load/selective packaging technology. In order for remote supply sources to provide on-demand sustainment, a rapid method for selective offload must be developed. Supplies and equipment must be readily located and selectively offloaded from ships, aircraft, and/or standard containers and then repackaged for delivery by guided unmanned aerial delivery systems.

MAJOR UNCERTAINTIES

The technological risks and costs associated with GPS-guided and self-powered parafoils may prove prohibitive. Moreover, the energy sources required to provide power and achieve the desired loiter time capability while not detracting from cargo carrying capacity are doubtful in the short term. In the interim, the fuel-to-cargo tradeoff for powered parafoils and logistics variants of a UAV may limit application to only small unit small payload missions. Control in flight and during take-off and landing of the powered versions (parafoils and UAVs) poses another uncertainty. Options for control range the spectrum from control by the receiver of the sustainment, control by the provider, and/or a dual control feature. When evaluating control issues, tradeoffs between burdening the maneuver combat units with organic logistics or burdening the units with potentially cumbersome control equipment for aerial resupply vehicles must be weighed.

RECOMMENDATION

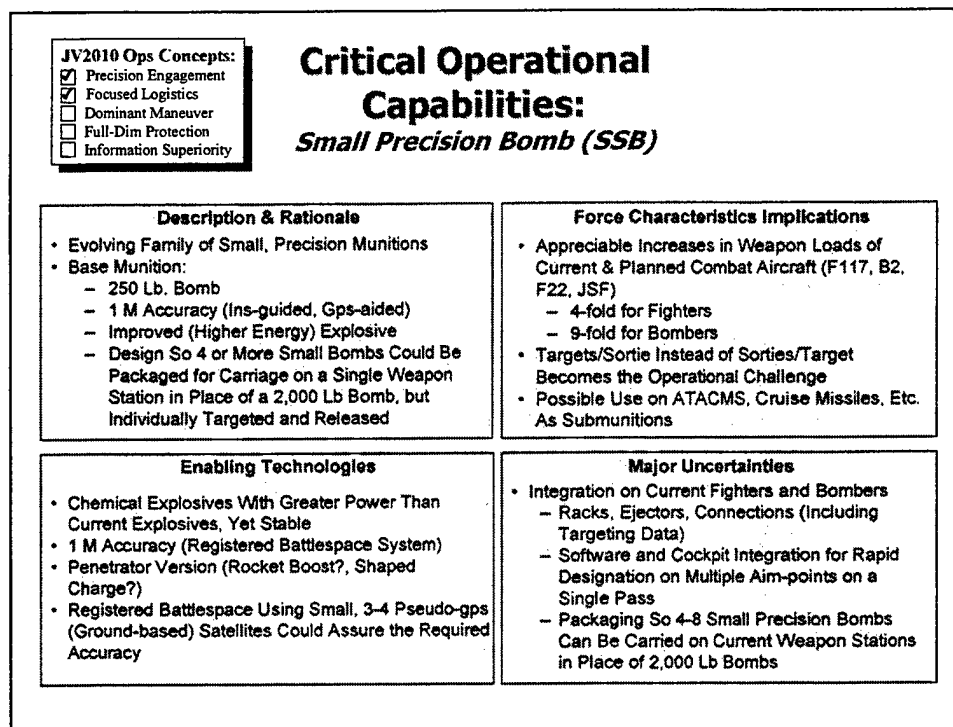
Conduct operational experiments with parafoils (powered and unpowered) and UAVs to develop and refine the concept, techniques, procedures, and technologies associated with providing sustainment in this manner. Continue to fund for experimentation to find innovative and efficient ways to enhance the sustainment of dispersed forces operating on the multi-dimensional (low to high intensity) battlefield of the 21st century.

AGENCY

Lead should be US Marine Corps and US Army. US Air Force and US Navy in supporting roles for air- and sea-delivered sustainment.

COST ESTIMATE

Cost of experimentation is estimated at \$10 million per year for 3 years. Cost for operational program would be based on results of the experimentation, mission-area analyses, and the surrogate technologies available after the experimentation.



DESCRIPTION & RATIONALE

A family of small precision bombs (SPBs) can multiply, by factors of four to nine the number of precision-guided bombs current and planned fighters and bombers (including the F-117, F-15E, F/A-18E/F, F-22, B-2, B-1, and JSF) could carry on a single sortie. Substantially reducing bomb size (volume) and weight while retaining the effectiveness of existing 1,000-2,000-pound bombs and munitions is especially important for stealthy platforms which must carry their strike ordnance internally to retain low observability and, hence, survivability.

In the context of developing SPBs for aircraft, the baseline munition would be a 250 pound bomb using improved explosives and improved accuracy compared to the 10-meter circular error probable (CEP) presumed for GPS-aided (Global Positioning System-aided), inertially-guided bombs such as the Joint Direct Attack Munition (JDAM) in clean environments with target-mapping (or target-location) errors of less than 5 meters. The two main improvements envisaged are:

- The development of explosives with perhaps 2-3 times the energy release of current warheads based on plastic-bonded explosives such as AFX-108 and PBXN-109¹; and,

¹ Naval Studies Board, National Research Council, *Technology for the United States Navy and Marine Corps 2000-2035* (Washington, DC: National Academy Press, 1997), Vol. 5, p. 46.

- Inertially-guided, GPS-aided bomb kits able to achieve one-meter accuracy in GPS-coordinate space (that is, ignoring target-location error). One meter accuracy requires what has been termed “differential” GPS.

The combination of foreseeable improvements in these two areas could allow a 2,000 pound JDAM to be replaced on a given aircraft by four to nine SPBs against the vast majority (about 85%) of targets for which 2000 pound bombs would be used today. (On a fighter-bomber weapon station able to carry a 2,000 pound munition, substituting eight, as opposed to four, SPBs is more a packing-and-volume issue than one of weight. The discussion will opt for the low end of the range on the assumption of limited volume. However, six to eight SPBs might be achievable on some aircraft with the right bomb designs.

The notion, then, is to increase dramatically the combat utility of existing munitions stations on current and planned aircraft. Should unmanned air combat vehicles (UCAVs) be developed, small, precision bombs would also offer reduced volume-and-weight precision munitions for these platforms. Thus, the SPB concept is applicable not only to the manned but to unmanned air-breathing platforms that seem likely to begin supplementing traditional aircraft in the early decades of the 21st century.

Potentially the explosive and accuracy improvements on which the SPB is predicated could also prompt the development of a comparable family of smaller munitions for the indirect fire support of ground forces, both from land and sea. The packaging issues for large-diameter mortar and artillery rounds are different than those involved in multiplying the carriage capacity of individual weapons stations on fighters and bombers. And much has already been done to provide tailored submunitions for use in weapons such as ATACMS and cruise missiles such as the Tactical Tomahawk. However, the possibility of migrating SPB technologies to the indirect fire support of ground forces should not be overlooked.

FORCE CHARACTERISTICS IMPLICATIONS

The force-multiplication implications of being able to load four or more 250 pound, GPS-aided SPBs in place of a single 2,000 pound JDAM across the entire fighter-bomber and attack inventories of the US Air Force, Navy, and Marines is significant. The SPB could provide a fourfold or greater multiplication of the existing inventory measured in terms of aim-points covered per unit of time. This multiplication offers the possibility of completing the functional disruption of specific target systems, to say nothing of entire air campaigns, in much shorter times than would be feasible with current air-to-ground munitions. Shorter completion times, in turn, increase the attack intensity a given force can bring to bear against particular target systems and, as a result, the chances of achieving functional collapse.

In the case of bombers, the potential multiplication of single-sortie weapon loads is even more dramatic. The B-2 can currently carry sixteen 2,000 pound munitions on rotary launchers in its two bomb bays, and some 76 500 pound JDAMs using more volume-efficient bomb racks. If each 500 pound JDAM can be replaced by two 250 pound SPBs, the single-sortie load-out would be some 150 independently targetable precision weapons – almost an order-of-magnitude increase over the number of 2,000 pound weapons the B-2 can carry on a single sortie.

Given the large increases in single-sortie weapon load-outs of individual aircraft the SPB would make possible, the fundamental measure of air operations against many target categories would shift from the number of sorties per target to the number of aim-points and targets per sortie. This change in the basic measure of merit for 21st century air operations is likely to permit smaller numbers of aircraft to deal with a given size contingency. It could also have long-term implications for traditional force packaging, which from World War II through non-precision air operations during Desert Storm in 1991 was driven by the need to put many sorties over a given target in order to destroy it.

ENABLING TECHNOLOGIES

While there has been discussion of order-of-magnitude or greater improvements in the energy release of advanced chemical explosives compared to nitramines such as HMX and state-of-the-art plastic-bonded explosives (PBXs), gains measured by factors of two to three seem far more likely to represent the maximum achievable over the next few decades. The technology assessment made for the US Navy and Marine Corps in 1997, which looked out to 2035, reached the conclusion that factor-of-two-or-three improvements are the most that can be expected over this timeframe in the penetrating power of miniature precision weapons against hard targets or armored fighting vehicles.² These judgments were based on the assessment that increases of two or three times the blast energy H₆ represented the most one could reasonably expect from foreseeable improvements in explosives (equivalently, a 1.4 increase in the lethal radius for a warhead of equal volume). These estimates appear to be consistent with those reached by the Defense Science Boards in its 1996 Summer Study.³

These points suggest that being able to achieve a 250 pound SPB with roughly the lethality of current 2,000 pound munitions against most targets will hinge more on accuracy improvements than more powerful explosives. Moving from 10-meter to 1-meter CEPs for GPS-aided, coordinate-based represents the rough magnitude of the accuracy improvement required. For an expeditionary force in an overseas area of operations (AOR), the Registered Battlespace System, discussed in Volume I, offers the most affordable and near-term solution. For this application the system consists of four transportable GPS "pseudo satellites." When implanted on precisely known ground locations, they can provide 1-meter geocoordinate positioning throughout an AOR 1,000-2,000 miles across. This system was described in the Defense Science Board's 1996 summer study.⁴ Many of the elements for a wide-area GPS system providing 1-meter accuracy were also demonstrated by the Air Force at Eglin AFB in mid-1995.⁵ Furthermore, in March 1997 the US Air Force successfully dropped two miniaturized, 250 pound bombs from a single F-16 at Eglin Air Force Base, Florida, and each bomb, using "differential GPS," "hit its target within the three-meter accuracy requirement."⁶

The final technological requirement for the SPB concept involves integration on existing aircraft. SPBs would require modifications to existing racks to carry and empty larger numbers of smaller. Perhaps even more important is real-time mission planning capability and cockpit

² Technology for the United States Navy and Marine Corps 2000-2035, p. 52.

³ Defense Science Board, *1996 Summer Study Task Force on Tactics and Technology for 21st Century Military Superiority*, October 1996, Vol. 3, p. III-3.

⁴ Ibid, Vol. 3, pp. III-74 to III-81.

⁵ Ibid, Vol. 3, p. III-76.

⁶ "USAF Completes Testing of Small, Smart Bomb," *Aerospace Daily*, 25 March 1997, p. 447.

integration so that aircrews can easily designate and drop against multiple aim points on a single pass across a given target or target area. The ability to designate 10 or 20 aim-points and match each with a particular munitions type within 1-2 minutes – including having the weapons-management software to automate everything else – is crucial if the full potential of SPBs is to be realized. Requiring the aircrew to make a separate pass for each SPB released for a distinct aim point is tactically unacceptable.

In addition, because of the large numbers of SPBs that could be carried on individual fighter and bomber platforms, mixed loads would be far more practical than heretofore. A large platform like the B-2 might carry SPBs with warheads tailored for many target types, such as area targets, soft targets, and hardened point targets. Thus the on-board targeting system would need not only to permit rapid designation of individual aim points, but also be capable of effortless and timely specification of the SPB-type to be employed. A related feature would be a capability to put a number of SPBs on a single aim point.

MAJOR UNCERTAINTIES

The technical uncertainties associated with the SPB concept, if viewed in conjunction with the presumption of a Registered Battlespace System able to provide one-meter or better location accuracy, appear to be minimal. For the most part the task appears to be engineering development of technologies that have already been demonstrated.

The dominant uncertainty, therefore, is whether the military services and the Department of Defense are willing to make the modest but sustained investments needed to field a family of small precision bombs. Since its March 1997 technology demonstration, the small bomb program at Eglin has been combined with LOCAAS (Low-Cost Autonomous Attack Munition) in a miniaturized munition program office. However, small bombs do not presently appear to be a high priority within the Air Force, nor are the Services committed to the registered battlespace system or other ways of providing “differential” GPS.

RECOMMENDATIONS

1. Proceed with the development of a family of small precision bombs
2. Tie this development to that of a registered battlespace system able to provide GPS local accuracies of one meter or less as well as increased resistance to jamming.

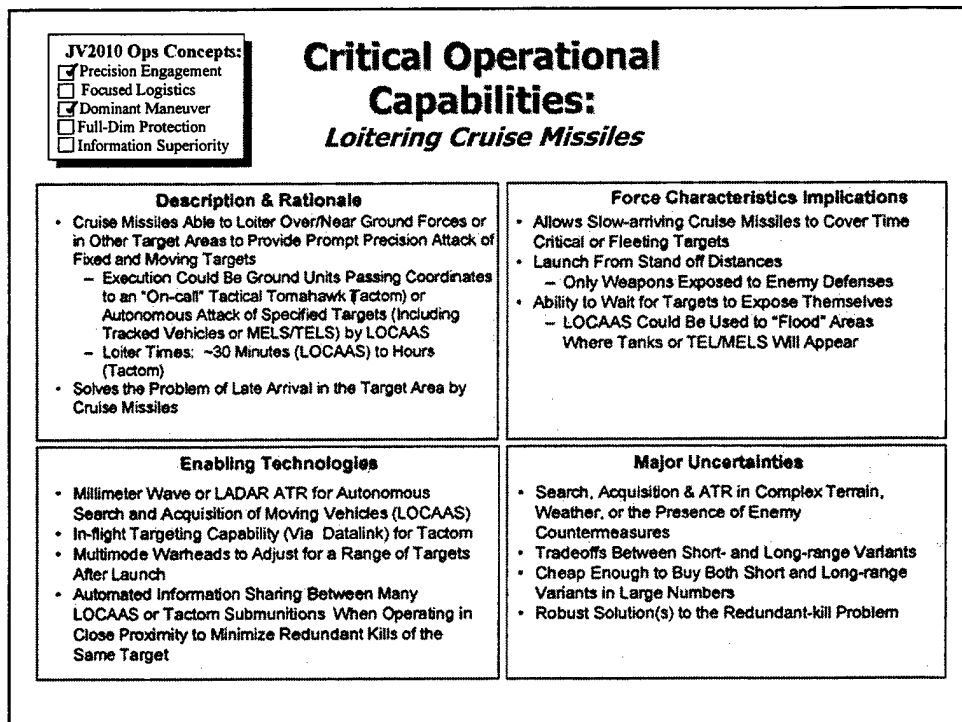
AGENCY RESPONSIBLE

USD (A&T) should direct the development of SPBs since the individual Services are unlikely to link miniature munitions and registered battlespace or to give these programs the sustained funding priority needed to field both small precision bombs and a registered battlespace system.

COST ESTIMATE

Funding estimates should come from the Miniature Munitions and GPS program offices. In the case of registered battlespace, the emphasis should be on a deployable, ground-implemented solution rather than space-based.

LOITERING CRUISE MISSILES



DESCRIPTION & RATIONALE

Giving subsonic cruise missiles the ability to loiter in the battle area and wait for fleeting or moving targets to present themselves addresses the tactical problem inherent in the time required for these weapons to fly from their launch points to intended targets. On the one hand, cruise missiles launched from standoff distances outside the reach of enemy air defenses have great appeal as an alternative to penetrating those defenses with relatively costly manned aircraft and delivering direct-attack munitions. On the other hand, cruise missiles such as Tomahawk can take an hour or more to arrive in the target area after being launched from a naval combatant offshore. Long transit times between launch and arrival at the target have been a major operational constraint on the utility of cruise missiles against targets requiring very prompt responses, meaning target-designation-to-impact times of less than five minutes. The concept of loitering cruise missiles offers a way of circumventing the "time-late" or "late-arrival" attribute of existing subsonic cruise missiles.

For fixed targets such as an electric power plant or a non-mobile command-and-control facility, it seldom matters if the time between missile launch and weapons impact is five minutes or more. Near simultaneous arrival of multiple weapons in target areas, or their coordination with other fires, is a scheduling problem.

However, in the case of pop-up, moving, or relocatable targets, the time-late problem can preclude tactical success. Consider a light, dispersed friendly ground unit without organic armor or heavy direct-fire support suddenly finding itself in close proximity to enemy armor. A 30-minute delay between the call for fire and weapons impact is unacceptable if the enemy armor is in a position to overwhelm the friendly ground unit in the next five or ten minutes. Fleeting targets such as mobile missile launchers offer another example of how the time-late problem can undercut the effectiveness of subsonic cruise missiles. During Operation Desert Storm in 1991, Iraqi mobile erector launchers (MELs) were rarely (if ever) detected prior to firing and, as the campaign unfolded, Iraqi MELs demonstrated an ability to vacate their launch positions after firing a modified Scud in as little as three to five minutes. The transit times of current and planned subsonic cruise missiles gives them little capability against such elusive targets.

A solution is to field cruise missiles able to loiter in close proximity to friendly ground forces or in other target areas. Two possibilities are the Tactical Tomahawk (TacTom) and the Powered Low-Cost Anti-Armor Submunition (P-LOCAAS).^{*} The Tactical Tomahawk is intended to be a more versatile, less costly update of the Tomahawk Land Attack Missile (TLAM). Among other things, TacTom will include a capability to be retargeted in flight, to loiter over the battlefield for more than two hours awaiting tasking, and to provide target assessment imagery. The US Navy awarded an engineering and manufacturing development (EMD) contract for the Tactical Tomahawk in June 1998, including firm pricing for 1,343 missiles over five years with production scheduled to start in 2002. TacTom is expected to cost less than \$600,000 each (or \$800,000 if remanufactured).

P-LOCAAS, by contrast, is much smaller and considerably cheaper under \$40,000 per round. P-LOCAAS offers a maximum range of nearly 100 nautical miles and an endurance of 30 minutes. It uses a three-dimensional LADAR (laser detection and ranging) to search for imprecisely located targets (over a footprint of 0.5 x 2 nm) and contains automatic target recognition (ATR) algorithms to identify and distinguish among all types of ground vehicles, such as specific surface-to-air missiles, MELs, tanks, or civilian vehicles. P-LOCAAS, which is being developed by the Air Force, also includes a GPS receiver and a data link. LOCAAS was successfully tested from a light airplane in 1994 and powered, free flying versions in 1998.

TacTom and P-LOCAAS span large differences in unit costs and loiter times (or search areas). They also represent different approaches to dealing with imprecisely located targets or targets which can change their locations. In general, a retargeted TacTom would go to a set of GPS coordinates and release submunitions such as BAT (Brilliant Anti-Tank) able to home on moving targets using a combination of acoustic and infrared sensors. P-LOCAAS, by comparison, can actively search for specific target types using ATR algorithms and even has a three-mode warhead (single-rod penetrator, stretching rod, and fragmentation) which it can match to the target. The LOCAAS data link can be used to target update a loitering LOCAAS and it can be used to determine bomb damage assessment. In addition, P-LOCAAS may be more safe to employ with friendly ground vehicles nearby than TacTom with BAT. Despite these

^{*} See next section on LOCAAS.

differences, though, both weapons illustrate how the operational utility of subsonic cruise missiles could be greatly improved by enabling them to address a class of imprecisely located or moving targets for which they have heretofore been ill-suited due to the time-late problem.

FORCE CHARACTERISTICS

In general, the force-level implications of loitering cruise missiles depend on the probabilities of kill (P_k s) likely to be achieved by individual rounds in the case of P-LOCAAS and individual submunitions in the case of TacTom/BAT. The long-term goal should have P_k s in the neighborhood of 0.5 or higher. Anti-vehicle submunitions such as sensor fuzed weapon (SFW) and BAT can probably produce this level of performance today in open terrain, (such as desert) against relatively simple arrays of vehicles. However, contrary to the widespread impression that the problems of precision weapons have been largely solved, realistic P_k s for BAT and SFW submunitions in complex terrain (hills, foliage, and urban build up), against complex target arrays, or in the face of enemy countermeasures are probably closer to 0.1 than 0.5. While these limitations can be solved with steady product improvements, they illustrate the uncertainties inherent in assuming similar levels of performance by TacTom and P-LOCAAS across the gamut of terrain, target arrays, and enemy countermeasures.

That said, loitering cruise missiles with round/submunition P_k s around 0.5 against moving or fleeting targets would have far-reaching force-level implications. First, the munition efficiency would be considerably higher than achieved with most previous precision weapons (excepting laser-guided bombs, (which approached a 0.5 P_k in 1972 in Southeast Asia). Second and more importantly, achieving the level of efficiency envisaged for loitering cruise missiles would reduce the munitions logistic burden. At a campaign level, P_k s of 0.5 or higher would offer a fivefold reduction in the number of weapons that would have to be expended in comparison with the number required by weapons with a 0.1 P_k . Tactically, P_k s in the vicinity of 0.5 would make it much more feasible for commanders to flood specific target areas with loitering cruise missiles. (Being able to operate this way with friendly forces and vehicles within range would, of course, demand near-zero false alarm and misidentification rates.)

ENABLING TECHNOLOGIES

TacTom and LOCAAS exemplify divergent technical solutions to target acquisition and attack. TacTom would wait in a target area for someone to pass it a target assignment – probably, as a minimum, GPS coordinates and, in the case of attacking moving armor with a submunition such as BAT, information on the orientation of the enemy formation. Beyond a secure data link for retargeting and access to GPS, TacTom, presumably, would technically be a modest risk weapon.

P-LOCAAS, on the other hand, is not only smaller and cheaper, but it is predicated on reliable ATR (including low probabilities of mistakenly attacking the wrong target type or failing to attack the intended type). Key technologies required by LOCAAS, therefore, include:

- Algorithms and a sensor for wide-area search;
- ATR good enough to distinguish tracks from wheeled vehicles and mobile missile launchers from similar-sized vehicles; and
- A multi-mode warhead able to adjust for a range of targets, such as armored versus unarmored vehicles.

Another enabling technology applicable to both TacTom and LOCAAS in the long term is a way for individual loitering cruise missiles (or, in the case of TacTom carrying BATs, their submunitions) to share targeting decisions. A fundamental limitation of the basic BAT submunition is that multiple kills of the same target are dealt with by the geometrical dispersal of individual BATS relative to the target array. While this solution is simple and works in open terrain, it is likely to be much less successful in complex terrain. While a BAT P_k of 0.5-0.6 is not unreasonable in open terrain against road-bound target arrays, there is reason to think it might fall to 0.1-0.2 in complex terrain. An ability to share the targeting decisions of individual missiles or submunitions would go far to solve the redundant-kill problem.

MAJOR UNCERTAINTIES

ATR is thought by many to be either here or, at worst, just around the corner. The DSB's 1996 Summer Study "*Tactics and Technology for 21st Century Superiority*" argued that ATR equal to the challenge of enabling small and rapidly deployable ground units to defeat much larger enemy forces in a wide-area engagement "is now emerging from the laboratory."⁷ ATR able to cope with complex terrain, weather, and enemy countermeasures may remain a substantial technological barrier to overcome despite widespread expectations to the contrary.

A robust solution to the redundant-kill problem is also a critical barrier to overcome before loitering cruise missiles can approach their full potential. This problem has been worked for some time by the ballistic-missile defense community, from where workable solutions for transfer to precision-strike operations might be found.

In addition to offering different technical solutions, TacTom and LOCAAS represent extreme differences in range and unit cost. Appropriate tradeoff studies, supported by rigorous operational experiments, will be necessary to determine the best mix of loiter times and costs-per-round. Intuitively, however, one suspects that a mix of longer- and shorter-range loitering cruise missiles would be the best solution, rather than fixing on a single type.

⁷ "Automatic Target Recognition (ATR) for Rapidly Deployable Outnumbered Forces in Wide-Area Engagements," Vol. 3, Oct 1996, pp. 11-88 to 11-109

RECOMMENDATIONS

1. Proceed with the development of Tactical Tomahawk as a long-range, high-end loitering cruise missile.
2. Ensure the development of a shorter-range less costly loitering cruise missile, the best candidate now on the horizon being P-LOCAAS.
3. Link the two loitering cruise missile developments together as a package for dealing with imprecisely located or moving targets. Doing so seems important because TacTom is a Navy program while P-LOCAAS is an Air Force program and is currently a low priority development by that Service.
4. Finally, the responsible program offices should be directed to begin the product improvement work to ensure that these weapons, as well as any anti-armor submunitions they may employ (such as BAT in the case of Tactical Tomahawk), undergo improvements aimed at enabling them to cope with complex terrain, complex target arrays (such as two armored columns crossing one another through an intersection), and enemy countermeasures (such as movement exploiting hills, foliage, other terrain features, or timing to minimize losses to anti-armor submunitions). Also fusing of weapons which must penetrate foliage to hit their target must be addressed and extensively tested.

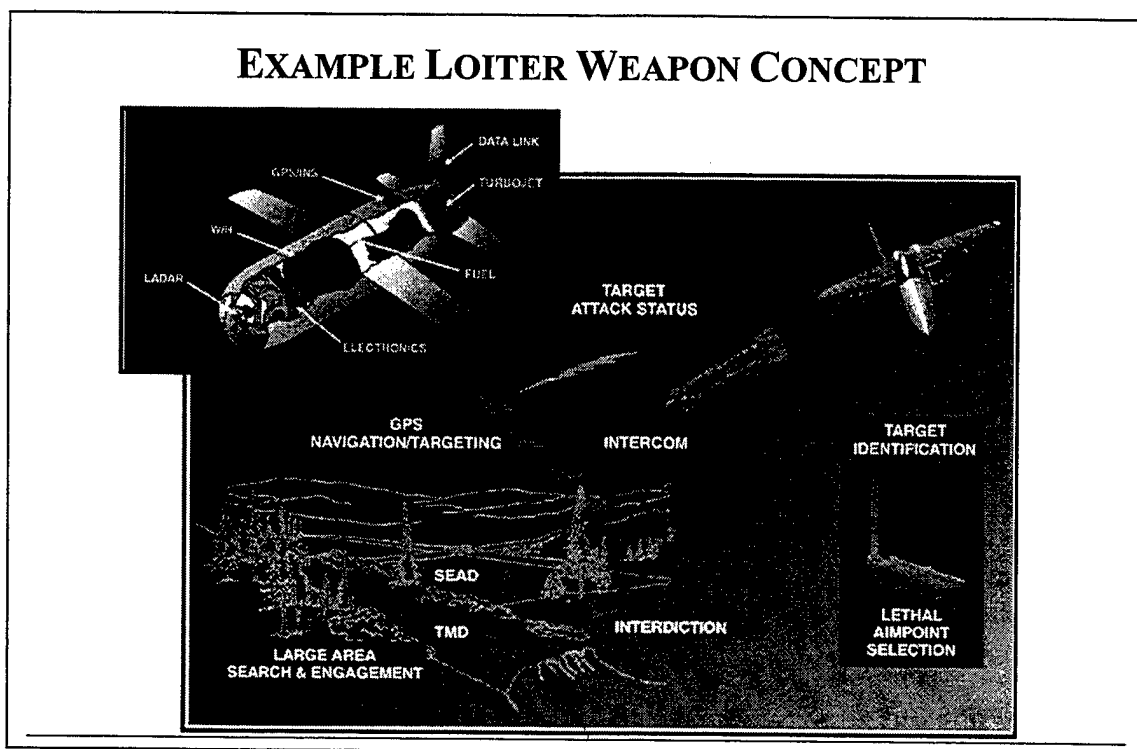
AGENCIES RESPONSIBLE

The program offices for Tomahawk, LOCAAS, and BAT should be directed to implement these recommendations, with OUSD/A&T assigned responsibility for ensuring compliance.

COST ESTIMATE

Consider a \$50-100 million plus up to Tactical Tomahawk, P-LOCAAS, and BAT programs to analyze and test what needs to be done as product improvements in each program. Later-year adjustments would depend on the product improvements each weapon requires to achieve the desired Pks regardless of terrain, target arrays, and enemy countermeasures.

LOITER WEAPON CONCEPT – LOW COST AUTONOMOUS ATTACK SYSTEM (LOCAAS)



Over the past eight years, the US Air Force and Army have been sponsoring the development of a smart munition called Low Cost Autonomous Attack System (LOCAAS). The LOCAAS is designed to loiter and autonomously hunt for targets, report what it finds, and kill the highest priority target. It can be delivered by aircraft, munitions dispenser, rocket, or missile.

After dispensed by its delivery system, the vehicle wings/fins are deployed and the turbojet engine is started. The Global Positioning System/Inertial Navigation System (GPS/INS) navigates the munition to the search area. The vehicle descends below the cloud layer and begins to search with its Laser Radar (LADAR) seeker. Potential targets are located and either attacked immediately (depending on assigned priority) or their location is stored for possible later attack. Many potential separate target types can be stored in its onboard memory and additional targets can be added in the field. Just before warhead detonation, an attack status message is sent back to the shooter via data link. Other munitions in the vicinity monitor transmissions so that multiple attacks will be avoided, and if they do not find a target they can find and attack a target passed over by another reporting munition. This type of weapon is being designed to respond to targeting information generated by ground combat units for rapid direct fire support.

An unpowered version demonstrated LADAR search and guidance and was successfully flight-tested during 1994 and 1997. It will be flown twice more in the near future. The powered version is capable of 30 minutes of flight. The vehicle navigates with GPS and a low cost inertial

measurement unit (IMU). A cellular phone technology data link is employed to relay information collected by the munition and its attack actions back to the shooter as well as share information with other munitions in the vicinity.

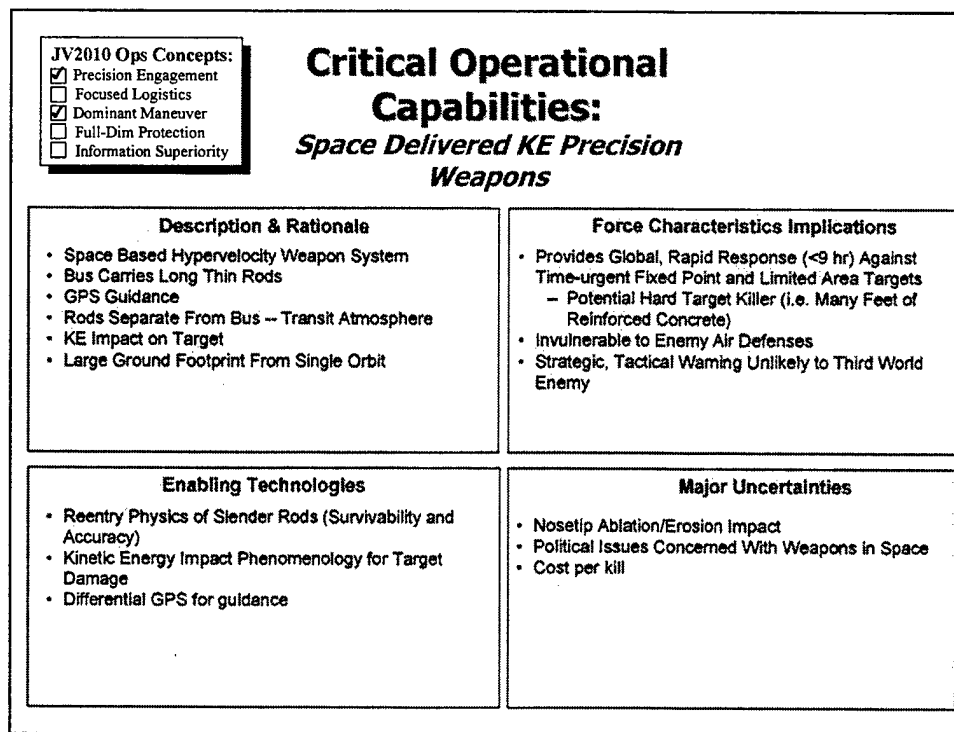
A powered vehicle was demonstrated in 1997 at White Sands Missile Range. It successfully navigated through a 19 nautical mile closed circuit course via GPS/INS. It flew in stable flight between six pre-selected GPS waypoints and data linked its position and status continuously.

The munition is designed to carry a multi-mode, explosively-formed-penetrator warhead. When detonated, it will form either a long rod penetrator, an aero-stable slug, or fragments. The target aimpoint and warhead mode are automatically selected by the weapon's Automatic Target Recognition (ATR) algorithms associated with the onboard LADAR imaging sensor. This combination of an imaging sensor and multi-mode warhead will allow the munition itself to tailor its lethality against different mobile targets (hard and soft). The multi-mode warhead has completed development at Eglin AFB. All three modes have met the lethality specified by joint Air Force/Army requirements.

Recently, the LADAR and ATR successfully completed a rigorous captive flight test at Eglin AFB and Redstone Arsenal. Over 3000 target encounters were achieved and nearly 700 square kilometers of search area were covered to generate false alarm rate (FAR) statistics. The government closely monitored the tests in which 75% of the data was sequestered for further analysis. Probability of Identification (PID) for Scud and surface-to-air missile radar vehicles was obtained. The levels of PID and FAR exceeded the entrance criteria for the next phase of the LOCAAS development. The Air Force stated that, "The STAR (LADAR) seeker Captive Flight Test (CFT), as a data collection, was a huge success. The STAR seeker CFT, as a demonstration of maturity of the powered LOCAAS technology was an even greater success."

The Air Force will begin a LOCAAS advanced technology demonstration in late 1998.

SPACE DELIVERED KINETIC ENERGY WEAPONS



DESCRIPTION AND RATIONALE

This weapon system consists of a constellation of space orbiting vehicles carrying long thin rods of a heavy material in highly elliptical orbits. Using GPS guidance, the bus deorbited and is guided toward the ground target with extreme accuracy. The rods separate from the bus before reentry into the atmosphere, transit the atmosphere in a very short time, and strike the target at hypervelocities (>10,000 ft/sec) with great (differential GPS) accuracy. The high velocity impact leads to a kinetic energy kill of the target. Appropriate orbits and reentry angles allow for a large ground target footprint from a single orbiting vehicle.

The successful development of this system would provide the United States with a capability to strike targets anywhere on the globe within six to nine hours depending upon constellation size and orbital parameters. In lieu of forward basing, ballistic delivery of precision weapons from space is the only feasible way to assure prompt attack of targets anywhere on the globe within the opening hours of the war and without using systems currently countable under the START Treaty. This weapon concept can be employed day or night and regardless of weather.

FORCE CHARACTERISTICS IMPLICATIONS

Space-delivered kinetic energy weapons provide a global, rapid response (fraction of an hour to hours) against time-urgent fixed point and area targets. Fixed missile launch sites, command and control centers, fixed radar sites, air bases, sheltered aircraft and other high value fixed

targets are potentially vulnerable to attack by this system. It has the potential of attacking some buried targets as well since the large kinetic energy carried by the rods enables penetration through many feet of reinforced concrete. A limited set of area targets, such as air base runways or armor staging areas, are potential targets for this system using a larger number of smaller rods. The kinetic energy delivered is less to these softer targets but the area covered is increased by the larger number of rods carried by the bus.

This system is invulnerable to the enemy's air defenses. Strategic and tactical warning is unlikely for many adversaries since it requires a sophisticated space-based tracking system to detect the deorbit of the spacecraft and subsequent flight to the ground. Changes in targeting parameters (within limits) can be made while the bus deorbits so that a commander can retarget the system if required. The attack can be stopped at any time prior to release of the rods from the bus by commanding the bus to reenter with the rods attached or reentry or reengage the bus propulsion system and "kick" it back into space.

ENABLING TECHNOLOGIES

The key enabling technologies are the survivability and accuracy of long slender rods reentering the earth's atmosphere at high velocity and the kinetic energy impact phenomenology upon striking the target. ICBM warhead reentry physics is a well-developed, well-understood technology. This concept relies on applying that knowledge to small radius nose tip designs. High velocity kinetic energy impact phenomenology is also a well-understood technology. This concept must make use of that technology base to establish the kill potential of this system against various target classes.

MAJOR UNCERTAINTIES

The most critical uncertainty involves the technical feasibility of the reentry of long, slender rods into the earth's atmosphere at high velocities. Reentry must occur without causing asymmetrical nose tip erosion, which would lead to unstable reentry dynamics, and breakup of the rods or large errors in target accuracy. Of secondary concern, is the potential for disrupting GPS guidance of the bus by pro-active measures taken by the enemy.

It is conceivable that some concern may be expressed by detractors to the concept regarding placing weapons in orbit. However, Article IV of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies states: "states' parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner." The Treaty was signed and ratified by the US Senate in 1967. Its terms do not appear to preclude the development and use of a space-delivered kinetic energy precision weapon.

RECOMMENDATION

Re-initiate and complete a demonstration program to show the feasibility of hypervelocity reentry of long slender and short rods into the atmosphere while retaining precise impact

accuracy. Increase support for research and development of kinetic energy impact phenomenology. Especially as it applies to attacking buried targets.

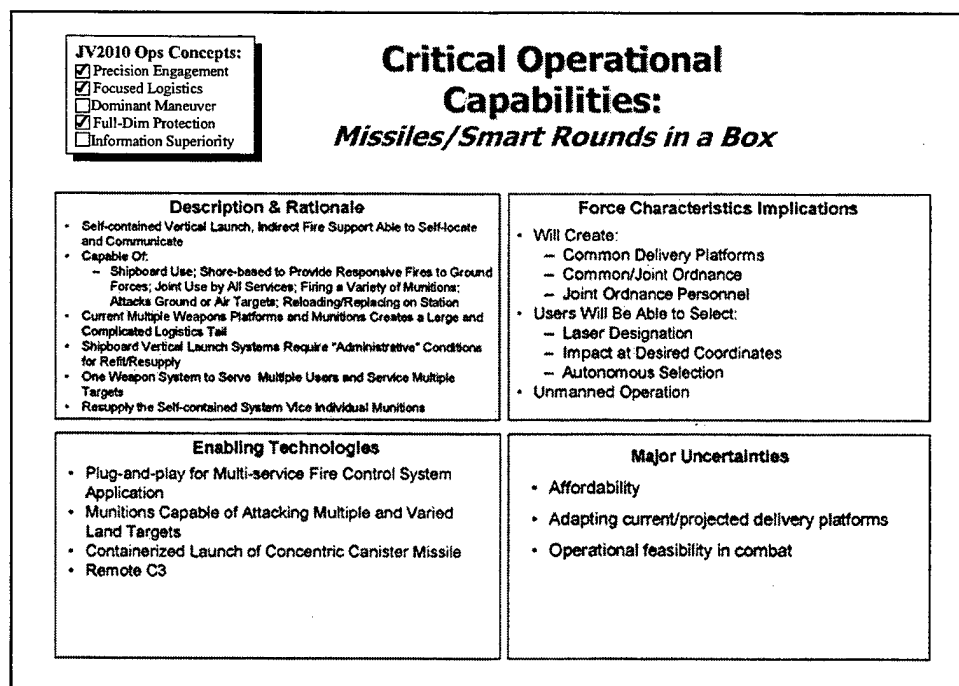
AGENCY TASKED WITH RESPONSIBILITY

1. Reentry and flight dynamics: DARPA and Air Force Phillips Lab.
2. Kinetic energy impact phenomenology: DSWA, now integrated into DTRA and Phillips Lab.

ESTIMATE OF COST/FUNDING

1. Reentry and flight dynamics: 3 year program, total cost \$50M. Assumes Air Force or Navy picks up cost of 3 ICBM or 3 SLBM launchers
2. KINETIC ENERGY impact phenomenology: \$3M-\$5M per year for a 3 year program

MISSILES/SMART ROUNDS IN A BOX



DESCRIPTION AND RATIONALE

The concept is a self-contained vertical launch, indirect fire support system. The relocatable and reloadable system consists of a standard cargo (ISO) container (8'X8'X20') loaded with various missiles and smart rounds. To provide intra-theater mobility the container would be transportable by fixed and heavy-lift rotary wing aircraft. Moreover, the cargo container would

include a C³ module for self-location and plug-and-play fire control with a common/joint service fire control system. Common fire control and communications architecture using the Integrated Information Infrastructure (III) will enable use by all services from either ship, land-based, space or airborne using the Integrated Information Infrastructure (III) platforms.

With the capability to fire a variety of munitions the "missile/smart round in a box" will be able to attack ground or air targets with equal effectiveness. The system should be capable of reloading on station, offering the potential to either reload on station or replace one "box" with another "box" to provide continuous indirect fires based on the tactical and operational picture. Finally, common weapons delivery via a truly joint fire support system will significantly reduce the logistics burden while increasing responsiveness.

FORCE CHARACTERISTICS IMPLICATIONS

A common-user weapons delivery platform (missiles/smart rounds in a box) provides the opportunity for a common/joint ordnance and joint ordnance personnel capable of supporting any of the weapon delivery systems or munitions. Additionally, this capability will facilitate dispersed, light, and agile forces that possess the capability to engage tactical targets with responsive indirect fires. The conceptual system and capability should provide these light forces with the ability to choose laser-designation impact at a desired location or autonomous selection of targets.

ENABLING TECHNOLOGIES

The "missile/smart rounds in a box" possesses enormous potential; however, this concept and capability hinges on several technology enablers. The key enablers that warrant further study and development include:

- Common, vice the current complicated and delivery system-based, logistics infrastructure capable of joint user sustainment and use.
- One weapon system and common munitions to service multiple users and targets. This technology enabler requires either versatile and selectable munitions or a variety of munitions in the same launcher (box).
- The ability to both resupply by container instead of individual munitions or resupply by refitting individual munitions on station if the tactical and operational situations permit.
- Plug-and-play technology for multi-service fire control system application. The services would require a common, plug-and-play, fire support system that allows the same missile/smart round box to be fired by any service from any location or platform.
- Standard missile guidance and propulsion technologies.
- Assured communication links between ground forces and supporting launchers or launch platforms.

- Smart missile front-end guidance systems and/or forward observer target designation capability.
- Munitions capable of attacking multiple and varied targets – missile and/or smart rounds capable of attacking air, sea, and ground targets.
- Containerized launch of concentric canister missiles.
- Fixed or rotary wing transportability of the “Missiles/Smart Rounds in a Box” containers for intra-theater transportability. This issue may also force the exploration of composite or lightweight materials in order to reduce the weight of the container and the weight of the munitions.
- C3 module for the “Missile/Smart Round in a Box” that, when mounted in container, provides the capability for self-location and plug-and-play fire control.

In addition to the technologies above, the rapid resupply of either container “boxes” or individual munitions for reloading the “boxes” on station warrants further exploration of selective off-load and selective packaging technology. Individual boxes or munitions for reload of the boxes must be readily located and selectively offloaded from ships, aircraft, and/or standard containers, configured for use and transport, and then rapidly delivered to ensure continuous indirect fire support.

MAJOR UNCERTAINTIES

The technological risks associated with unmanned, containerized missiles or smart rounds are the key uncertainties. Specifically, the feasibility of developing a common and truly joint family of munitions and launch platforms (boxes) could prove technologically or fiscally prohibitive. Moreover, the ability to adapt current and projected delivery platforms to new weapons delivery systems and a revolutionary approach to indirect fire support requires a fundamental shift in current thought. The issue of controlling fires in the battlespace (organic or supporting fires) and the assured communications infrastructure between human or remote sensors and the shooters (boxes) will require additional study and experimentation via an ACTD. Finally, procedures for resupply and/or reload on the battlefield or on station remain uncertain.

RECOMMENDATION

Continue to research and develop munitions, weapons, and weapons delivery systems to support this concept. DARPA is currently working an associated concept AFSS or “Arsenal in a Box” and has acquired costs and more specific technologies regarding this concept. Upon completion of the research and development by DARPA, the potential for an ACTD to expedite fielding this capability across the services may be warranted.

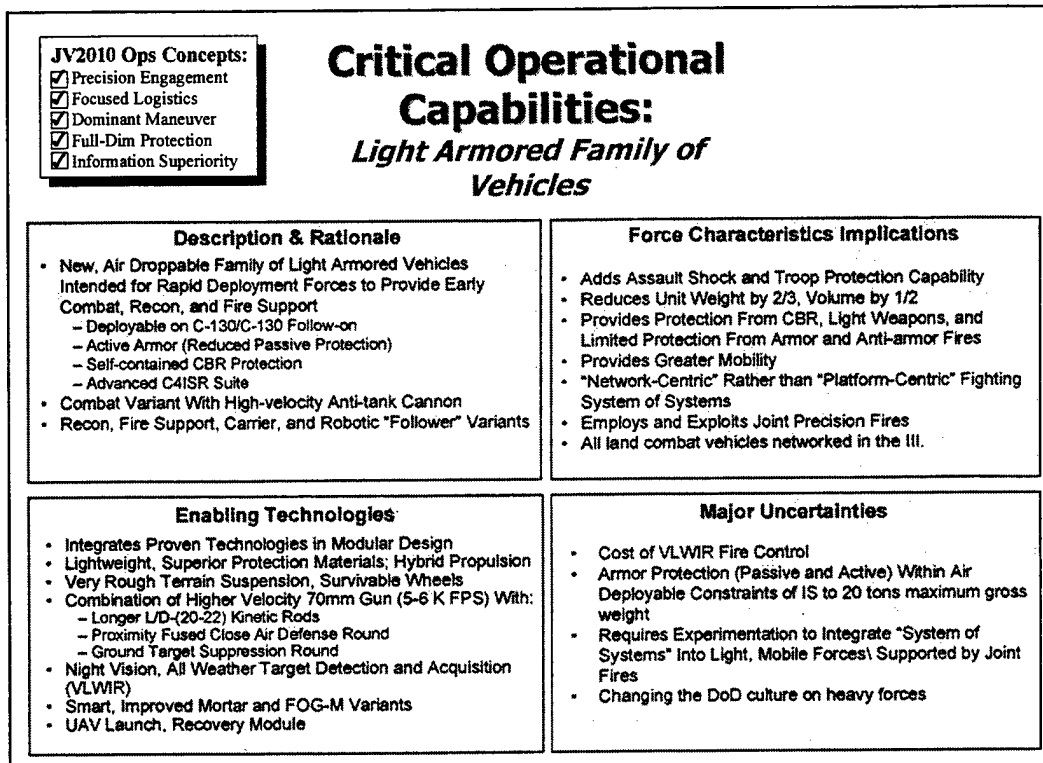
AGENCY

Lead should be DARPA with joint service participation until research and development is complete.

COST ESTIMATE

DARPA should be consulted for cost estimate.

LIGHT ARMORED FAMILY OF VEHICLES –LIGHT MECHANIZED STRIKE FORCE (LMSF)



DESCRIPTION AND RATIONALE

Today's heavy force is too bulky and cumbersome to be deployed in a crisis unless either strategic warning exists to provide buildup time in theater *or* heavy war reserve stocks and equipment are already prepositioned in exactly the right location. To be decisive in future conflicts, Joint Force Commanders (JFC) will require potent ground forces – on the ground within 24-48 hours and able to close with and destroy attacking enemy armored or mechanized formations – in order to control the depth and breadth of battlespace as envisioned in Joint Vision 2010.

To achieve this capability, a family of light armored vehicles must be developed that has the deployability of the current set of light forces *as well as* the lethality, survivability, and decisive capabilities inherent to traditional heavy, mechanized forces. To satisfy this design challenge, these new vehicles must be air deliverable by C-130 or follow-on transporters and equipped with the following systems: high velocity anti-tank cannon and internetted C4ISR suites to facilitate

the employment of precision fires from air, sea, space, and ground platforms; as well as active armor protection and self-contained chemical, biological, and Radiological (CBR) protection systems.

These design features, coupled with the system's strategic and operational mobility, will provide unprecedented capabilities for early entry forces from the strategic to the tactical levels of conflict. Variants within the family will provide reconnaissance, fire control, and combat service support to complement the primary armor killing systems. The use of robotic followers will enhance operations and provide protected, uninterrupted logistical support to ensure sustained operations. The light armored family of vehicles will be able to get to the theater of operation by strategic airlift to influence the initial fight, move within the theater, and move rapidly in the most restrictive terrain to achieve tactical objectives on a sustained basis.

FORCE CHARACTERISTICS IMPLICATIONS

These innovative design aspects will provide major advances for the force. The light armored family will deliver greatly enhanced assault shock capability while providing protection (anti-armor, ballistic, and CBR) for the crew. Deployable weight will be reduced by well over two-thirds of existing requirements, while cutting cubic volume by over one-half. This produces a major advance in strategic and operational mobility, which is further enhanced by its greater tactical mobility. The net effect will be to create a ground force with greatly increased roles in deterrence, preemption, and conflict termination.

Perhaps of greater importance in assessing overall system potency, is that the family is being developed using a "network-centric" rather than a "platform-centric" approach. This will enhance overall versatility, since it will ensure the means to harness the full range of precision fires envisioned in Joint Vision 2010. While Light Mechanized Strike (LMS) forces will certainly be able to secure key facilities, protect ports of entry, and control lines of communication, they will also be able to attack and destroy enemy armored and mechanized formations in independent or coordinated fashion primarily using precision indirect fires. In addition, their high reliability and energy-efficient designs will dramatically reduce requirements in three fundamental areas: supporting maintenance activities, strategic and intra-theater lift, and traditional lines of operation which emanate from large bases built up within theater. The combined effect of these capabilities will be to allow for a style of ground warfare that is far more decentralized, flexible, faster, and more effective than that with which we are familiar today.

ENABLING TECHNOLOGIES

The design of the light armored family of vehicles will integrate many proven technologies in modular fashion to achieve well-established parameters for deployability (and trafficability), lethality, and survivability. Five major new technologies, all well into commercial or military development, will be included.

The first key technology to be employed is lightweight, superior material. This will produce dramatic weight reductions which will greatly increase both deployability (by reducing aggregate airlift requirements by two-thirds and volume by one-half) and mobility (both within the theater

and in support of tactical commanders). The second major set of technologies will produce new levels of trafficability. The use of survivable wheels, with optional band tracks and sophisticated independent suspension, will create a near-all terrain capable platform. The use of hybrid propulsion sources – the third major technology – will provide the power plant needed to efficiently move this lightweight, highly trafficable chassis. While enabling longer combat range and endurance, these advanced hybrid propulsion systems will also greatly increase fuel efficiency and mechanical reliability.

The fourth major technology will contribute to enhanced lethality, by fielding both a line-of-sight medium caliber cannon and hyper-velocity missiles. This armament will feature high velocity (5,000-6,000 feet per second) tank-killing 70 millimeter automatic cannon that fire improved long rod penetrators (20-22 millimeter length-to-diameter ratio) at high rates. Variants will also carry beyond line of sight standoff missiles and precision guided mortars. The fifth major technology area includes the C4ISR suite that will produce a shared operational picture. Information technologies will be integrated to ensure crewmembers have situational understanding of friendly, enemy, and combat service support units. The advanced, internettted communications suite* will provide digital linkage to joint precision fire systems which will enable a ground combat cooperative engagement capability (CEC) with precision fires delivered by joint and combined platforms.

Although light, these materials will be safeguarded by active protection systems – the fifth major technology to be integrated. Active armor modular overlays will be employed to counter tank main gun rounds. The light armored family of vehicles, which will feature new levels of ground speed and combat range, it will also provide a high measure of ballistic protection for the smaller, two-three member crew – and will establish new standards in overall deployability, trafficability, lethality, and survivability (as measured by protection-to-weight ratios).

MAJOR UNCERTAINTIES

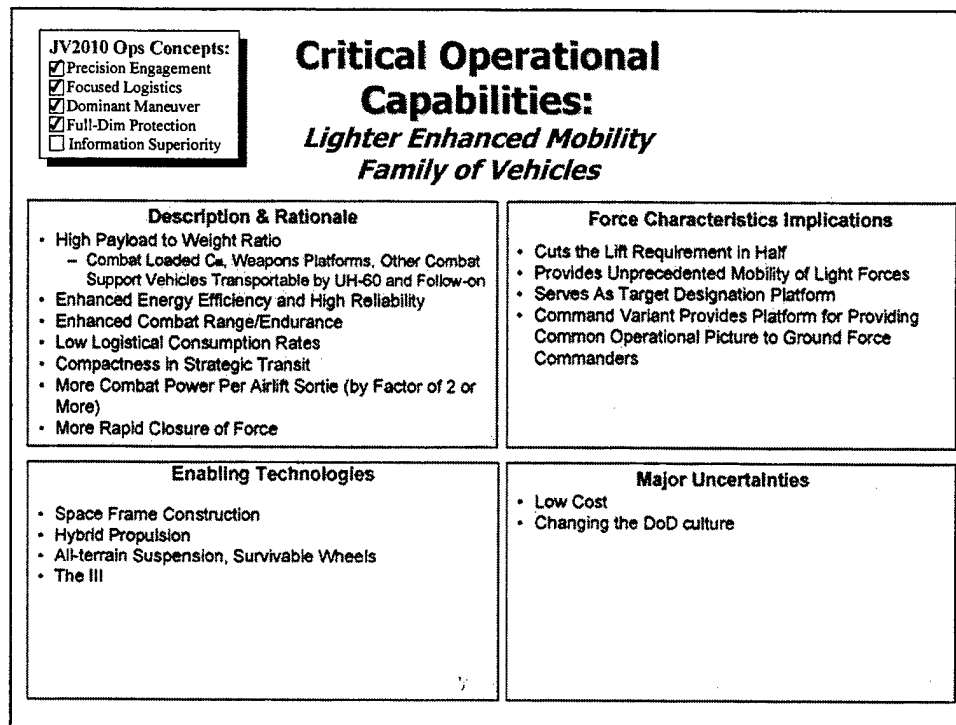
This new family of vehicles, as described above, is a “system of systems.” The only major uncertainty that exists (barring major setbacks in the realization of individual technologies) is a failure to pursue its development and fielding in this manner. Should resources be shifted away from advanced propulsion technologies, for example, the vehicle might need to be outfitted with heavier or less reliable drive train components. This would, in turn, reduce range, require more logistical and maintenance support, and add weight – all of which would run counter to the design parameters established for both deployability and trafficability. Similarly, if the commitment to develop either very long wave infrared fire control systems or improved passive and active armor protection systems falters, crew and system survivability might be put at risk.

RECOMMENDATION

The Army and Marine Corps should expeditiously proceed with a competitive new vehicle concept definition and development program with the assistance of DARPA and commercial vehicle manufacturers.

* See Volume I of this Report for a discussion of the proposed Integrated Information Infrastructure (III).

LIGHTER ENHANCED MOBILITY FAMILY OF VEHICLES – LIGHT INFANTRY RESPONSE FORCE (LIRF)



DESCRIPTION AND RATIONALE

Rapidly deployable early entry forces are designed specifically for early crisis response – a role that requires them to be not only fully airlift deployable and tactically mobile, but also to be highly lethal. Light forces of today, while the most deployable of Army and Marine Corps units, lack the firepower and potency to cope with full-spectrum warfare demanded by Joint Vision 2010. The family of light vehicles designed for the Light Infantry Response (LIR) force, employs a tubular space frame design and a common chassis for all variants, which will provide dramatically new tactical capabilities. Three aspects of the design serve to illustrate the design of the vehicles, which comprise this new family. First, they provide a high payload to weight ratio. The three major variants – weapons platforms, command and control vehicles, and combat support vehicles – will all be able to be transported by the UH-60L and the MV-22, even when fully loaded. The larger vehicles in the family, primarily logistics and weapons platforms, will all be able to be moved by the CH-47D, the C-130J and their follow-on designs. Second, the enhanced energy efficiency and high reliability designs for the drive train and major components will increase both combat range and endurance. Third, the compactness of the design will increase strategic and in-theater transit capacity. Since these vehicles will be designed to fit within existing and projected aircraft or to be sling carried, aggregate airlift capacity will increase significantly.

FORCE CHARACTERISTICS IMPLICATIONS

These innovative aspects of the light vehicle design provide major capability advances for the force. The high payload to weight ratio increases their overall potency and provides the Joint Force Commander (JFC) with the ability to rapidly project combat power to secure key facilities, protect ports of entry, and control lines of communication. LIR forces will have unprecedented speed and mobility that will enable them to perform essential functions of target designation for precision fires, reconnaissance, and command and control, as well as sustaining themselves.

With this family of new, light vehicles, their longer range and higher reliability provides them with greater freedom of action, flexibility, and responsiveness. Their design characteristics will also reduce requirements for supporting maintenance activities and equipment. In addition, while their strategic air deployability will get them on the ground between 24-48 hours after receiving orders to deploy – which increases their roles in deterrence, preemption, and conflict termination – their tactical mobility will be virtually unprecedented.

As an example, consider the impact their design will have on their air assault capability. Because all the vehicles can be moved by UH-60L, CH-47D, MV-22 or follow-on aircraft, a force can be rapidly relocated on the battlefield – in its entirety. This will eliminate the requirement to control supply routes, which routinely dissipates combat power, divides the focus of leadership, and puts repositioned forces at great risk since they are separated from their water, ammunitions, rations, and other supplies until the logistics convoys reach their new area of operation. This new dimension in tactical air assault operations will enable LIR forces to be employed much faster to block enemy advances, retain key terrain, attack by fire, or control precision air, sea, space, and ground fires during the execution of massive, combined arms ambushes that will defeat enemy formations.

ENABLING TECHNOLOGIES

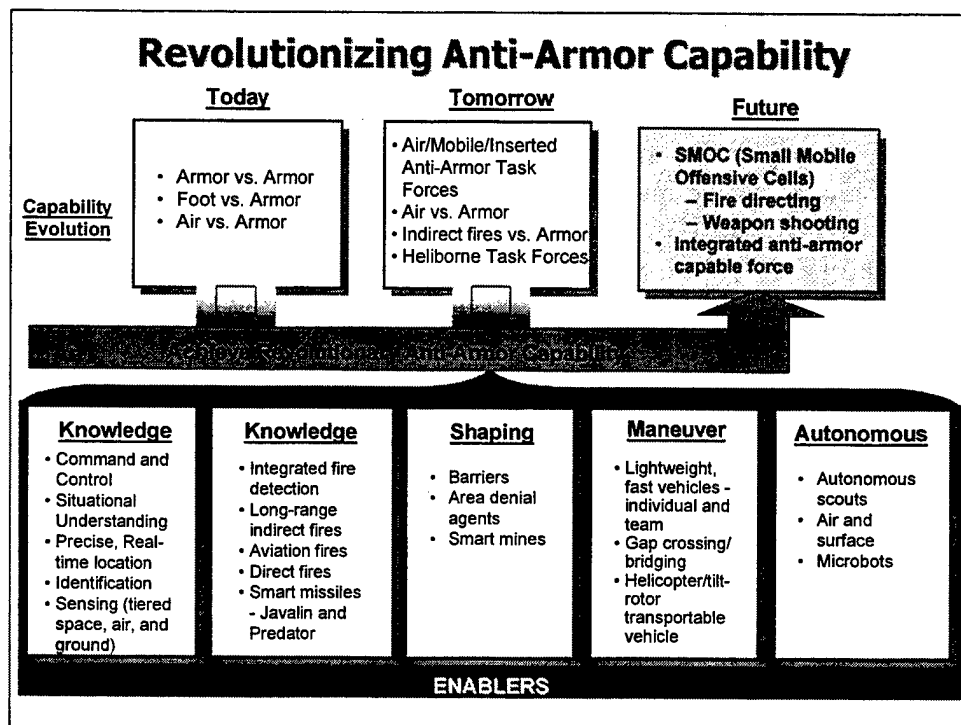
The first key technology to be employed is the lightweight tubular frame design. The frame is not only strong, it is light. The frame will be designed to complement future airlift design and will be stackable during flight. This will more than double existing airlift capacity. Mobility will be enhanced using all terrain capable, rugged independent suspension and traction systems. Hybrid propulsion systems will be used to ensure more than adequate power, high reliability, fuel efficiency, and overall extended endurance. Information technologies will be integrated to ensure situational understanding of friendly, enemy, and combat service support units and their operations. The advanced, internetted communications suite will provide digital linkages to joint precision fire systems which will enable cooperative engagement capability (CEC) for the land battle. On board weapons systems (both guns and missiles) will provide active ground and air protection.

MAJOR UNCERTAINTIES

The family of vehicles needed to support the LIR is a "system of systems." The only major uncertainty that exists (barring major setbacks in the fielding of individual technologies) is a

failure to pursue its development and fielding in this suggested manner. Should resources be shifted away from advanced propulsion technologies, the vehicle might need to be outfitted with heavier or less reliable drive train components which would, in turn, reduce range and require more support. Similarly, if support dissipates for the development of the lightweight logistics vehicles in the family, then the LIR might be saddled with the logistics challenges (“tooth to tail” ratios) that conventional light units face today, just to sustain themselves during continuous operations.

ANTI-ARMOR CAPABILITY



JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>Anti-Armor</i>		
Description & Rationale <ul style="list-style-type: none"> • Shift toward lighter, more lethal forces. • Lighter forces will require responsive fires to counter armor operations. <ul style="list-style-type: none"> – Environment will range from highly dispersed battlespace to massed armor threats. – Need will exist for lethal and non-lethal fires. 	Force Characteristics Implications <ul style="list-style-type: none"> • SMOC (Small mobile offensive cell) <ul style="list-style-type: none"> – Fire direction – Weapon shooting • Less emphasis on "tanks" and tank-like vehicles. • Greater emphasis on man-portable systems, fast attack vehicles, and indirect, precision fires. • Anti-armor vehicles will be deployable internal to rotary-wing and tilt-rotor aircraft. 		
Enabling Technologies <ul style="list-style-type: none"> • Locating <ul style="list-style-type: none"> – Tiered space, air, and ground sensors; Robots/roaming sensors • Channelizing <ul style="list-style-type: none"> – Area denial agents; Collapsible barriers; Smart mines • Lethals <ul style="list-style-type: none"> – Anti-armor first attack vehicles (V-22/Helicopter compatible) – Family of lightweight, man-portable, fire and forget systems – Indirect, precision anti-armor fires – Indirectly fired anti-armor minefields • Non-lethals <ul style="list-style-type: none"> – Engine inhibitors; "Boot" devices 	Major Uncertainties <ul style="list-style-type: none"> • Parochialism/Old-Think/Culture • Ingenious countermeasures • Ability to have and retain comprehensive battlespace situation understanding 		

DESCRIPTION AND RATIONALE

The end of armor as a dominant force on the battlefield has been proclaimed many times, yet armored vehicles continue to play a major role in traditional armed conflict and will for years to come. Given the proliferation of modern weapons systems and their export throughout the world, US forces can expect to confront adversaries equipped with armored vehicles, whether main battle tanks, infantry fighting vehicles, or armored personnel carriers. For the foreseeable future, adversaries will have access to a wide variety of tanks and armored vehicles. By the year 2015, a number of countries will have armor of a quality roughly equal to today's state-of-the-art equipment. Second tier countries will possess less capable vehicles that will still serve to intimidate their neighbors and provide local superiority. Overall, more than 100,000 main battle tanks and 200,000 other armored fighting vehicles are expected to be in service worldwide in 2010 and beyond. Some of these may prove exceedingly difficult to destroy. Modern design trends for tanks and armored fighting vehicles emphasize stealth, jammers, self-screening obscurants, and improved self protection, to include reactive armor and munitions countermeasures that defeat explosive anti-armor systems. Armored vehicle designers are also seeking greater mobility and weapon accuracy, combined with improved "shoot-on-the-move" and day/night engagement capabilities.

Hostile armor may appear in any type of conflict. While US forces must be prepared to deal with enemies who possess large inventories of advanced weapons, it is just as likely they will encounter armored systems in the hands of local insurgents or urban rioters during military operations other than war in which the local government has broken down and lost control of military equipment.

Anti-armor operations will be strongly affected by the peculiarities of terrain. Many potential adversaries are in desert areas where the terrain supports large maneuver forces and open fields of fire. In littoral regions, which tend to be broken by natural features such as rivers and river deltas, the terrain minimizes the value of armored maneuver elements, but does not eliminate armored vehicles as a potential threat. Urban combat forces are likely to encounter enemy armor in the course of conducting operations in urbanized terrain. Further, the presence of large numbers of noncombatants and many sources of nonmilitary signatures in this environment complicate the anti-armor targeting problem.

As the emphasis for employing of US forces shifts to rapidly arriving at the objective, large heavy armored forces become a logistics burden on the joint force commander. US forces should therefore shift toward lighter, much more lethal anti-armor forces that can quickly respond to crises worldwide. These forces will require both lethal and non-lethal fires to meet the anti-armor challenges in environments ranging from a highly dispersed battlespace to a compact urban area. Technology can provide a significant contribution to meeting the anti-armor needs of tomorrow's forces.

ENABLING TECHNOLOGIES

Technologies must emphasize innovation in locating, channelizing, and destroying the threat – the latter using both lethal and non-lethal means. Technologies that could enhance locating and engaging armored threats include:

- ***Tiered sensor systems****. A tiered system of space, air, and ground sensors would provide depth in locating armor. The system should possess all-weather, multi-spectral, acoustic and SIGINT capabilities that are linked through robust communications networks to all appropriate elements of the joint force. The system of tiered sensors needs to provide near-real-time situational understanding across the battlespace. To maintain tempo and avoid wasting munitions, the system must be capable of detecting and classifying decoys and of making timely and accurate battle damage assessments.
- ***Robots/roaming sensors***. Microbots and unmanned aerial vehicles (UAVs) could provide one tier of real time reconnaissance and location information to commanders. Micro-robots equipped with sound and visual sensing devices could be used to scout likely locations for armor, especially in urban areas and track armor within the battlespace. Similar to the microbots, micro-sized UAVs (with little chance of detection) could be used to reconnoiter localized areas and track the movement of enemy forces.
- ***Tagging***. US forces will need to be able to place a 'tag' on enemy armored vehicles. Tagging allows commanders to track vehicles until such time that the timing of the engagement is in the favor of friendly forces.

Channelizing causes the enemy to move in a predetermined direction desired by the opposing commander. Technologies that can assist in channelizing armor include:

* See the Volume I discussion of the III.

- **Barriers.** US forces should have the ability to rapidly erect barriers that deny or inhibit armored vehicles from entering an area.
- **Smart mines.** The joint force should have the capability to remotely deliver smart anti-armor mines. Remotely delivered minefields should be temporary, recoverable, or self-destructing either on schedule or by signal when no longer needed. Because maneuver forces have limited carrying capacity, recoverable anti-armor mine dispensing systems should also be developed as well. Deployed in easily transportable containers, such a system could be remotely activated to dispense mines in the event that an armored threat appears, then be rendered safe and recovered for reuse, as the situation requires.

Possibilities of fighting against armor in open, foliage covered, and urban terrain should drive technological innovation toward developing both lethal and non-lethal means to destroy/disable armored vehicles. New technologies in lethal munitions that could prove beneficial to anti-armor operations include:

- **Anti-armor fast attack vehicles.** The need to rapidly deploy to operations worldwide demands that logistic footprints be reduced. Light forces deployed by airlift will be the first US forces to arrive at the scene of a crisis to link-up with their coalition partners. The limited availability of air and sea lift will require that forces be equipped with light, fast attack anti-armor vehicles. Movement within the objective area will demand that these vehicles be capable of transport internal to helicopter and tilt-rotor aircraft.
- **Family of lightweight, man-portable, fire and forget systems.** A family of organic direct fire weapons will provide accurate, lethal anti-armor fires while being effective against other targets – perhaps through selectable or scaleable warheads. Weapons will be easily handled by an individual, simple to operate, soft launch capable, and available throughout the force in large numbers. The weapon should be able to quickly acquire the target and be fired without the operator maintaining track on the vehicle. These weapons should be able to either defeat frontal armor or reliably achieve firepower or mobility kills.
- **Indirect, precision anti-armor fires.** Indirect fire precision munitions optimized for anti-armor engagements will employ self-contained seekers capable of identifying armored targets and may deploy multiple submunitions. Each submunition will function as an independently targeted anti-armor attack system, providing a capability for multiple engagements from a single ordnance delivery. Cost-effectiveness is a critical consideration in the design of precision anti-armor munitions. These systems must possess the technological sophistication to successfully engage enemy armor at a cost per kill that does not reduce their availability. When friendly ground forces encounter organized combined arms forces in open terrain, enemy armored systems must be separated from their supporting infantry. Thus, the requirement exists for not only precision, lethal and non-lethal anti-armor fires, but also accurate, high-volume suppressive fires. Indirect-fire systems must possess sufficient responsiveness, mobility, accuracy, sustainability and lethality against armored targets to provide an

all-weather, long-range capability during periods when naval surface and aviation fires may be unavailable.

In the urban environment, employing lethal munitions against armored vehicles may result in excessive collateral damage and civilian casualties. Non-lethal anti-armor technologies could include:

- ***Engine inhibitors.*** Engine inhibitors could be either statically located or remotely controlled vehicles. An electronic pulse directed into the body of the vehicle, potentially rendering the engine inoperable or engine injection of "containment" should be looked into.
- ***Rapidly deployable barriers***

FORCE CHARACTERISTICS

New concepts for conducting anti-armor operations are on the horizon. Lighter forces will require new organizations and weaponry to effectively contend with and destroy/neutralize armored vehicles in future conflicts.

The Small Mobile Offensive Cell (SMOC) concept is an example of an organization that typifies this new approach. The SMOC, operating from fast attack vehicles or helicopters/tilt-rotor aircraft would serve as the principal means of engaging armor threats. SMOCs would have the capability to direct aviation, indirect, or direct anti-armor fires on targets or would possess a limited organic capability to engage targets independently. SMOCs would capitalize on the ability to deploy with fast attack vehicles as internal or sling loads in helicopters and tilt-rotor aircraft.

In weaponry, the same basic munitions will be used by both ground and aviation anti-armor systems. Fuzing options will be available for the attack of field and urban fortifications, rotary wing aircraft, UAVs, and area/soft targets. The dismounted launcher will enable individuals to "fire and forget" from defilade positions. Ideally, ground units will deploy with weapons that are capable of engaging targets beyond line of sight and that possess a limited overhead loiter capability. Equipping US forces with a variety of weapons and technologies will provide flexibility and limit vulnerability to countermeasures.

Inexpensive, individual anti-armor weapons will require every US service member to be trained to identify and defeat enemy armored vehicles. This training must go beyond classroom, simulator, and technical instruction. Because much of the danger posed by armor is psychological, US forces must receive realistic field training that familiarizes them with anti-armor combat and gives them confidence in their ability to defeat enemy armor by both lethal and non-lethal means.

MAJOR UNCERTAINTIES

A new approach to combating armor – one which places light, mobile forces above heavy tanks – will require a drastic change in mindset capabilities and doctrine. Progressive thought in this area will prove to be the key enabler to designing lighter, more adaptable forces.

Another uncertainty concerns innovations in anti-tank countermeasures. Science and industry must anticipate innovation in this area and design effective munitions that are able to defeat emerging countermeasure technology.

RECOMMENDATIONS

- Create an experimental Small Mobile Offensive Cell
- Develop small fast attack vehicles
- Develop new family of anti-armor weapons
- Continue innovations with lethal and non-lethal anti-armor weapons
- Experiment with all of these initiatives

CHAPTER 2.

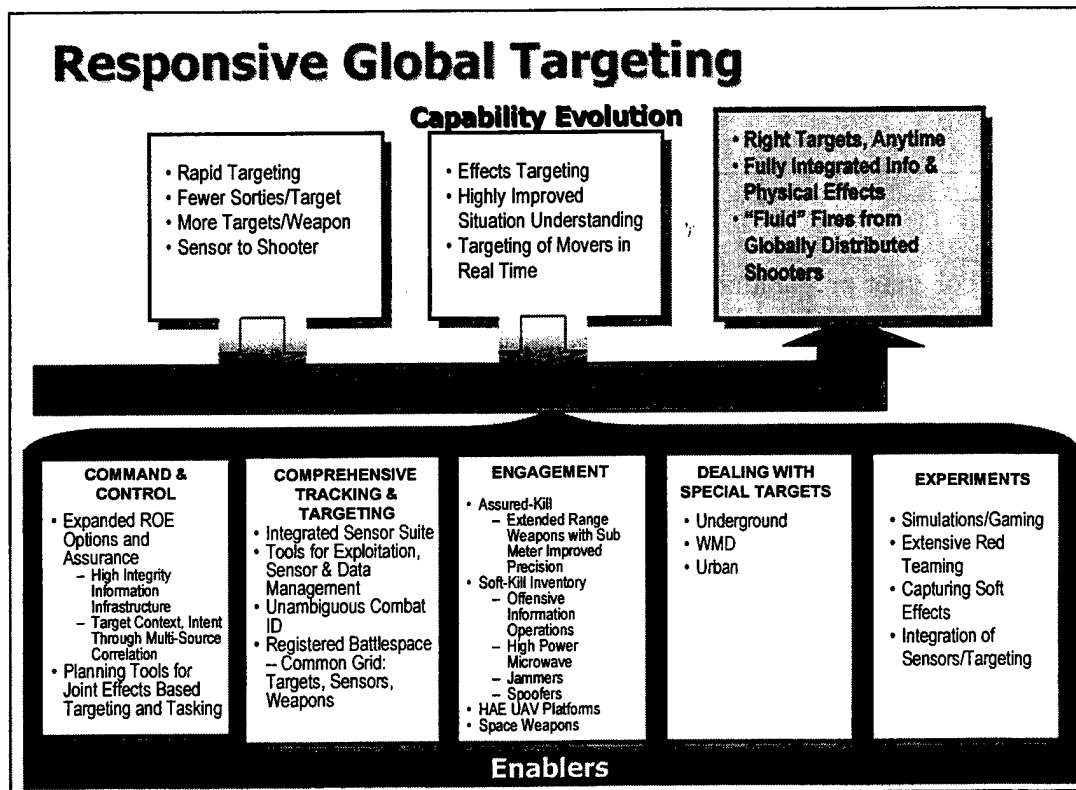
Responsive Global Targeting

CHAPTER 2.

Responsive Global Targeting

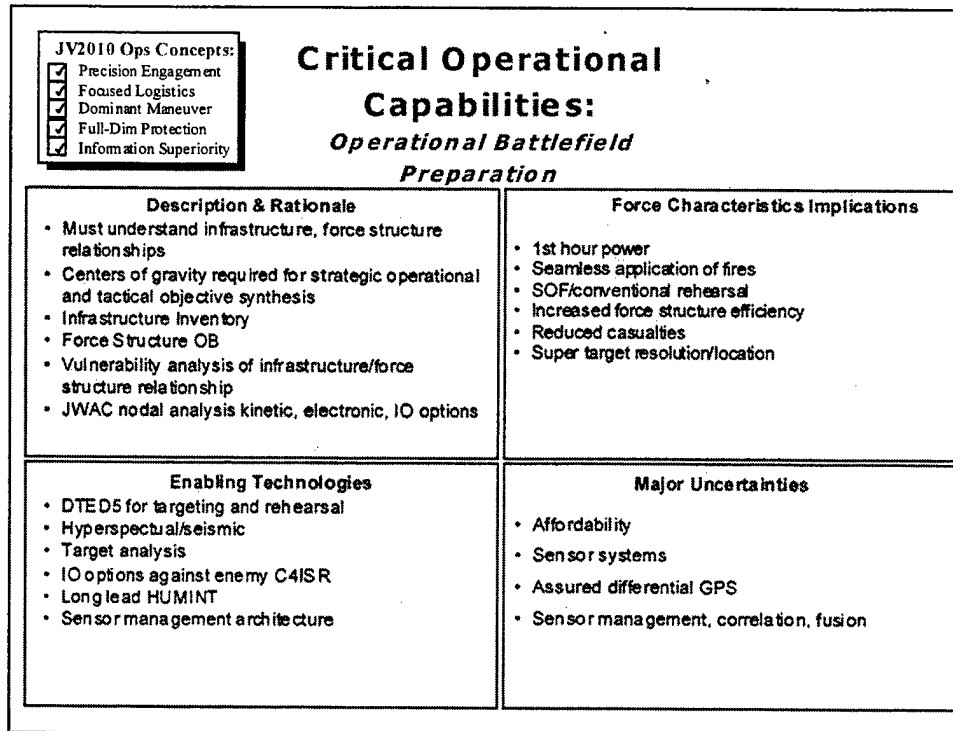
One of the critical operational challenges described in this study is responsive, precision targeting on a global scale. The vision is the ability to unambiguously identify, classify and precisely locate potential targets; establish priorities for engagement; determine the desired effects; and provide the means to deliver the desired effect at the right point in space and time anywhere in the world. This concept requires advances in command and control, tracking tactical targets and targeting, and engagement that together extend flexibility and effectiveness well beyond what current and near-term systems can provide.

The figure below depicts the enablers and the capability evolution for achieving “Responsive Global Targeting.” There are significant technical and operational challenges that need to be addressed to achieve this ambitious goal. Some of the enablers required for responsive global targeting are also necessary to achieve early combat effectiveness and knowledge superiority.



Volume I describes several key enablers to achieving a revolutionary responsive global targeting capability: command and control, comprehensive tracking and targeting, registered battlespace system, and engagement. This section describes a related enabler, operational battlefield preparation.

OPERATIONAL BATTLEFIELD PREPARATION



Today the coherent preparation of an area for the application of force is predicated on the intelligent application of US combat power. This discretion is mandated by political and practical considerations. Not only must the application of force be proportional but must conform to a series of unwritten norms in term of collateral damage and civilian casualties. From a practical perspective lethal force begets lethal enemies.

The efficient application of force requires an understanding of the opposing force culture, force structure and infrastructure. The strategic, operational and tactical centers of gravity are a function of the interaction of these factors. These considerations are important for all levels of conflict. Preparation is as important for operations other than war, as it is for a lesser or major regional conflict.

The critical enabling technology is the development of a common geolocational referent. The leading candidate for this is space-based interferometric synthetic aperture radar. This system could be used both as a mapper and an imager. The accuracy of this referent will define the options available to the commander. It is for this reason that a space based IFSAR mapper is required to produce accuracy at DTED 5. Supporting this IFSAR mapper/imager is a family of sensors. A hyperspectral passive system and active frequency agile laser for laser spectroscopy. The combination of an IFSAR, hyperspectral and laser based spectrometer starts to define the potential of a geographic information systems (GIS) database.

The refresh rate of the GIS must be inside the evolution timeline of the cultural features of the target. An important consideration in understanding the evolution of a target set is the use of machine processable discriminants where possible. To maintain an electronic order of battle

(EOB) will require the ability to detect, identify and characterize all signals. The depth required of the EOB will allow the association of specific emitters to units and operations. The ability to tag signals (with meta data) will allow the direct integration into the GISs.

High value/time critical targets are another critical component for the GIS. These targets require a combination of spectral depth and realtime retrieval. These characteristics must be defined and integrated into the data bases long before an engagement. To detect and characterize ballistic missile launches in real time will require the use of sensors with faster frame rates than those envisaged for SBIRS high or SBIRS low. Incorporating see to ground bands and real time processing like Cobra Brass will meet requirement to identify ballistic missile launches based on the spectral definition of the missile launch ignition spike. The fast framing requirement is met with Cobra Brass. Real time processing is an ongoing upgrade for Cobra Brass. The see-to-ground characteristics of all Cobra Brass systems permit refined impact prediction and warning timelines. This ability alone has the potential of reducing the losses from indirect fires by greater than 66 percent. The use of Cobra Brass in this role could increase the efficiency of radar like AWACS and the Aegis Spy 1 by as much as an order of magnitude. The fast framing character of Cobra Brass has the potential to provide for the first time actual kill assessment as opposed to simple hit assessment. The kill can be defined within the context of characterizing of the impact plasma – a discrimination that requires greater spectral depth than any previous sensor. At intercept speeds of 4km per second and faster, ample energy will be available for analysis. The energy produced by an exo-atmospheric intercept of an enemy missile can determine whether the warhead is a high explosive or biological or chemical weapon warhead if the data bases have sufficient spectral depth. Cobra Brass could be converted to missile warning and battle management support faster and cheaper than any comparative construct.

The key to GIS integration is change detection across multiple discriminants tied to a single geolocational referent at least accurate to DTED 5.

These characteristics support four fundamental concepts. First; the proposition that we want more than detection – characterization. Second; these phenomenon permit the transition from reconnaissance to surveillance. This means robust, near-continuous observation of the battlefield without the possibility of single node failures. Third; a move from the sensor-centric stovepipes that characterize today's systems to an information-focused approach to sensor management. This means the integration of the primary product into a geospatial organizing construct. By using unclassified data as direct inputs and meta data where information is classified, the access to information that focuses on understanding the relationships between sensors and objects will be simplified. Fourth, the capability will provide an operational continuum not just C4ISR. The intent of this transition is to meld the individual disciplines of C2 with the communication and intelligence discriminants to form an operations driven information organization. The objective is to span the continuum from operations other than war to a full major regional conflict. These four constructs, if integrated, have the potential of transforming how US forces will step into the opening decades of the 21st century.

In summary, these technical discrimination phenomenologies include IFSAR, for mapping and change detection, hyperspectral passive imaging, active laser spectroscopy, primary and complex SAR products, seismic and acoustic spectroscopy, real time nonimaging infrared (Cobra Brass), and most important, the integration of human intelligence and human intelligence support systems. Together they can transform how we do business.

The depth of and access to these databases is a key consideration for the future. Depth is important for both technical and human intelligence data base development. The depth of the databases defines the options available to the commander in future operations. To achieve this depth will require the integration of sensor management into the information management and network management subcultures.

In technical collection, depth is required for first order, change detection, second order, evolution and third order, historical perspective. The critical attributes of depth are sufficient historical record to understand changes. This includes changes in cultural features as a surrogate for changes in capabilities or behaviors. To understand the erection of a new building complex for example, a chemical processing facility the analyst needs to understand a sequence of events. That this facility is producing nerve agents requires understanding a very different sequence of events supported across very different discrimination phenomenologies.

In human intelligence depth has a different connotation. Depth here has the quality of very deep connections with the past. From a human intelligence perspective the evolution of human endeavor is a process of motivation, acculturation, education, training and potentially action. This is a process of years.

The timelines associated with each level of involvement makes the detection of a planned event a matter of months to years. A cell dedicated to a specific action can be expected to become more conscience of OPSEC the closer they get to the actual operation.

Detailed training of high payoff specialists will be observable but will require even greater database depth. Truly dangerous participants will likely be derived from an aggrieved population. They may be selected very early and receive their training in the west. The association of advance degreed personnel with terrorist organizations will be of the highest priority.

Terrorist organizations will probably take advantage of genuinely dedicated bright individuals who are pursuing education for personal ends. Recruitment of these specialists will be most successful when the specialist is associated with aggrieved populations. Whiting participants are most probable where the individuals professional stature is not compromised.

This selection of terrorist cell members then has both an experiential breadth and a professional depth.

The operational preparation of the battlefield is dependent on intelligence community databases. These databases must have temporal depth and the discriminatory breadth to access the evolution of the support infrastructure. The emphasis on leadership tracking has been demonstrated to be the least efficacious application of resources.

Transitioning from a detection based system to one that moves toward characterization and ultimately understanding should be the goal of Joint Vision 2010.

RECOMMENDATION

The Director, Central Intelligence (DCI) and the Secretary of Defense needs to establish a specialized group to provide detailed operational battlefield preparation information.

CHAPTER 3.

Exploiting the Littoral Battlespace

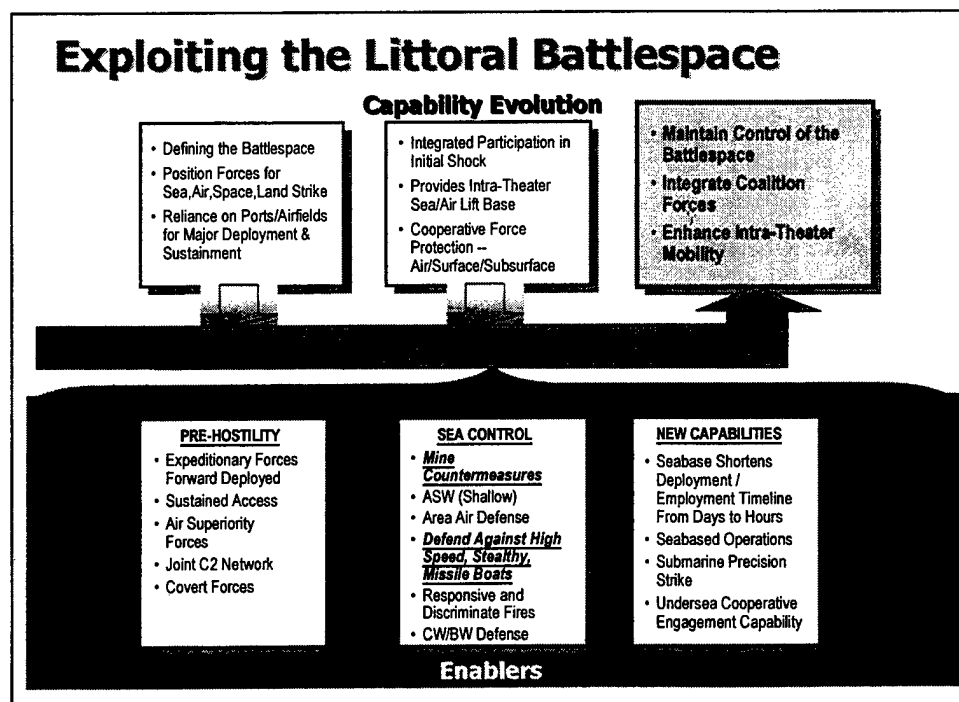
CHAPTER 3.

Exploiting the Littoral Battlespace

To influence events overseas requires a credible, forward-deployed, power projection capability. The United States needs to maintain the capability to project power ashore against all forces of resistance, ranging from overcoming devastated infrastructure, to assisting a friendly people in need of disaster relief, to countering the entire spectrum of armed threats.

Forward-deployed maritime forces provide for scaleable expeditionary forces. These forces make a major contribution to the five key elements of the Joint Vision 2010 concept of operations to achieve battle space dominance. They are an asymmetrical strength that can respond expeditiously to changing and unexpected events.

The clear need is having superbly trained, fully combat ready forces able to globally deploy to a potential conflict within hours of the decision to do so. Ability to dominate the littoral battlespace is critical to success in many likely contingency situations.



The top half of the figure above describes the evolving operational capabilities that are needed for exploiting the littoral battlespace. The enablers across the bottom of the chart build on the enablers needed for early and continuous combat effectiveness, assured knowledge superiority, responsive global targeting, intra-theater mobility, and other operational challenges such as urban operations discussed in Volume I of this report. Volume I discussed the enablers highlighted in the chart above. This section covers several additional enablers: air superiority forces, offensive mining, and undersea cooperative engagement capability.

AIR SUPERIORITY FORCES

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>Air Superiority Forces</i>	
Description & Rationale <ul style="list-style-type: none"> • Forward deployed aircraft carrier battle group • Rapidly gain and maintain freedom of action in littoral • Totally self-contained and supported strike force • Interoperability of AF, and air superiority assets (CEC) • Sustained portable air superiority <ul style="list-style-type: none"> – Deterrence – Protection of friendly forces – Strike enemy center of gravity – Provide instantaneous offensive air support 	Force Characteristics Implications <ul style="list-style-type: none"> • Provide early unique asymmetric air power for littoral battlespace dominance • Independence from overseas bases • Self-contained force projection • Air Superiority 	
Enabling Technologies <ul style="list-style-type: none"> • Assured sea control capability • Joint C2 networks • Increased sustainable sortie rate • Advanced aircraft arming and servicing • Smaller precision weapons -- more lethal but less logistics stress • Combat ID • Wider bandwidth links • CEC in the cockpit • Stealth/LO • Mix of UCAV and piloted aircraft 	Major Uncertainties <ul style="list-style-type: none"> • Availability (as conflicts increase, the number of CVBG could become inadequate) • Adversary stealth and air defenses in general • Integrated anti-access area defense systems 	

DESCRIPTION AND RATIONALE

The forward deployed aircraft carrier battle group is a totally self-contained and supported strike force that provides asymmetric air superiority. It can provide instantaneous long-range precision strikes against the enemy's center of gravity from greater than 1,000 nautical mile range. To control the littoral and achieve freedom of action, air superiority is paramount. The carrier battle group satisfies these requirements. A carrier battle group is totally self-contained and brings with it portable air superiority that provides deterrence, instantaneous offensive air support, strike at the enemy's center of gravity, and friendly force protection.

FORCE CHARACTERISTICS IMPLICATIONS

A forward deployed carrier battle group provides independence from basing and allows self-contained force projection and insertion that is highly maneuverable. Early asymmetric air power for littoral battle space dominance cannot be achieved any other way.

ENABLING TECHNOLOGIES

There are many technologies that would enable today's carrier battle group to become an even more effective projection force to exploit the littoral. A few of the more salient are:

- Smaller precision weapons that are more lethal and require less logistical support,

- Advanced aircraft arming and servicing,
- Assured sea control systems, and
- A mix of UCAV and piloted aircraft.

These technologies will permit increased sustainable sortie rates which with advanced joint C² networks, will allow fire power to be applied as never before, and air superiority anytime and anywhere. Additionally, there are over 120 single frequency, single purpose, narrow band, mechanical, and low gain antennas on carriers that, because of the power aperture issues, seriously limit available bandwidth. All of these antennas are competing for the apex of the mast. There is a great need for phased array, shared aperture, broadband, wide bandwidth, and high gain antennas for naval ships.

MAJOR UNCERTAINTIES

As the number of global conflicts increase, the adequacy of the number of carrier battle groups comes into question. The number of available carrier battle groups will have an impact on overall US crisis response and determine the number of conflicts that can be accommodated.

OFFENSIVE NAVAL MINE WARFARE

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input type="checkbox"/> Information Superiority	Critical Operational Capabilities: Offensive Mining	
Description & Rationale <ul style="list-style-type: none"> • Seed mine field at time, place, and duration of our choosing • Enhances force protection, limits threat's maritime options, and facilitates friendly maneuver • Organic deployment capability • Regeneration capability • Remote activation/deactivation • Control location • Port closure • Coastal ASW • Sea area denial 	Force Characteristics Implications <ul style="list-style-type: none"> • Unescorted ops • Force multiplier for subs • Amphibious exclusion zones • "Big" counter mine cost to enemy 	
Enabling Technologies <ul style="list-style-type: none"> • Acoustic communication link • Stealth • Miniaturized motor • Underwater "GPS" • Improved sensors • Improved batteries 	Major Uncertainties <ul style="list-style-type: none"> • International restrictions • Fratricide cost • Navy investment and commitment 	

DESCRIPTION AND RATIONALE

Offensive mining is conducted by US and coalition/allied forces either in waters under the enemy's control or in international waters that serve as sea lines of communication for friendly forces. By delivering mines into the littoral seas from surface, subsurface, and aviation platforms, joint US forces can shape the offensive battlefield while protecting its own and coalition forces against enemy seaborne forces. Offensive mining missions include port and naval base closure, coastal anti-submarine warfare, area denial, riverine, and defensive/anti-invasion. By fielding mines that can discriminate targets, engage or disengage on command (perhaps cooperatively), and be reliably decommissioned without endangering friendly forces, forces can control the enemy's access to the littorals while retaining freedom of action for joint operations. While mines were used extensively in World War II and in Viet Nam, their currently indiscriminate nature and concerns about third parties and fratricide have limited their use in modern conflicts. Current inventories are nearing the end of their service lives. The Department of the Navy is making very limited investments in new offensive underwater mine technologies.

FORCE CHARACTERISTICS IMPLICATIONS

Future mines should be capable of long-range detection, classification, and tracking of quiet surface and subsurface targets, cooperative engagement through a surveillance network, and battle damage assessment prior to reengagement. Depending on the mission, target type, and environment, naval mines should also be capable of limited self-deployment, mobile attack, and repositioning. Naval mines can serve as a force multiplier for joint operations by increasing the area of denial for ASW and ASUW forces, reducing the requirements for escort of amphibious ships and logistic craft, providing seaward screens for land-based operations, and acting as screens for points of entry in littoral operations. For operations other than war, naval mines can contribute to efforts to control communications and commerce to ports, estuaries, and coastlines; protect coalition forces from asymmetric seaborne attacks; and restrict adversaries' ability to conduct close surveillance of coastal operations.

ENABLING TECHNOLOGIES

Naval mines must be covert, robust, lethal, and offer the lowest possible threat to friendly forces. For these reasons, future naval mines should be constructed of advanced, high-strength/low signature materials; should be sufficiently survivable and reliable to be deployed weeks or months ahead of need; must be able to discern and engage a range of targets; and should be capable of remote activation and deactivation. Enabling technologies will include advanced composite materials; long-life/high-power batteries; acoustic and non-acoustic sensors; highly reliable, two-way, low-probability of intercept underwater communications; advanced signal processing; automated target classification and data correlation; and autonomous/distributed systems controls. Of these, underwater communications by ELF, VLF acoustics or lasers represent both the greatest challenge and the greatest potential enabler, particularly as they contribute to an undersea cooperative engagement capability.

MAJOR UNCERTAINTIES

Mining the enemy's territorial waters is permitted under international law, as is mining in the vicinity of enemy naval units. High seas mining is also permitted in the course of military operations for defense of land territory, sea lines of communication, and friendly naval forces. The use of remote control mines could extend the legal use of mines in international waters by reducing the threat to commercial shipping and permitting friendly forces to pre-seed selected areas without providing an undue threat to mariners. Placing mines in third-party waters – such as interdicting Iraqi waterborne traffic in Iranian waters for a Persian Gulf blockade – is more problematic, and while a technological solution may exist it seems unlikely that it would answer the political perception that this would constitute an act of war against a third party. Recent international conventions on the use of land mines will increase the relative importance of the ability to remotely deactivate mines and the political sensitivity of unplanned attacks on third parties.

Other uncertainties include the ability of friendly forces to conduct operations in the vicinity of intelligent naval mines without becoming unintentional targets; the ability to develop relatively low-cost (disposable) sophisticated underwater weapons with a long shelf life; proliferation of underlying technologies; and the ability of enemy forces to develop effective countermeasures, particularly with respect to an underwater communications capability.

RECOMMENDATION

The Navy needs to initiate a major offensive naval mine R&D program at \$50M per fiscal year beginning in FY00.

UNDERSEA COOPERATIVE ENGAGEMENT CAPABILITY (CEC)

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>Undersea Cooperative Engagement Capability (CEC)</i>	
Description & Rationale <ul style="list-style-type: none"> • Network of sensors, platforms, and weapons systems with improved computer processing of detection that provides situation understanding and targeting 	Force Characteristics Implications <ul style="list-style-type: none"> • Improved cooperative prosecution of undersea threats • Common, shared undersea warfare picture 	
Enabling Technologies <ul style="list-style-type: none"> • Undersea data links • Multi-static acoustic sensors and innovative distributed processing • Shallow water weapons systems • Real-time oceanographic environment assessment and prediction capability • Offboard tethered and untethered underwater vehicles 	Major Uncertainties <ul style="list-style-type: none"> • Bandwidth and data rate limitations of a acoustic signals <ul style="list-style-type: none"> – Environmental – Operational • Detection avoidance • Countermeasures • "Bottomed" (inert) targets 	

The ocean environment offers an adversary an opportunity to deploy asymmetric sea denial capabilities cheaply and effectively. Mines, submarines and remote sensing devices can be deployed in advance of hostilities in key ocean areas with the expectation their assets will be survivable through at least the early stage of a conflict. Adversary objectives would be to disrupt the tempo of operations or damage high value units to undermine the will to carry out a sustained engagement.

Denying the enemy an ocean sanctuary is a complex task involving application of high technology and closely coordinated combined arms forces.

A joint force commander relying on sea-based platforms for execution of his battle plan will want high confidence that submarines and sea mines can be negated as threats. To achieve freedom of action for coordinated theater-wide operations, the undersea threats must be thoroughly eliminated or intentionally avoided. A comprehensive network of sensors capable of mapping the oceans in the area of operations would provide the necessary integrated, undersea picture. Optimum effects would be achieved if weapons delivery platforms were linked to this network for rapid kill or negation.

Based upon an adequate understanding of an adversary's deployment of undersea capabilities, the combatant commander can choose to use maneuver, combat power or information operations as counters. The undersea picture would be provided from integration of distributed sensors on, above and below the sea, utilizing real-time oceanographic assessments of the environment. The network would rely on acoustic and fiber optic data links for undersea sensors and platforms as well as high bandwidth RF to link with spaced-based, airborne and surface nodes.

Just as the concepts for Area Air Defense have been advanced through the introduction of cooperative engagement capability (CEC) on Aegis cruisers, and other platforms networking of sensors, platforms and weapon systems with advanced computer processing would enable dramatic improvements in undersea warfare capabilities.

Intermittent contact gained at long range by the networked sensors would be immediately coordinated with detection by other platforms or used as cueing for prosecution by mobile sensors. The power of multiple nodes in this network expands with the number and variety of sensors employed. Remote underwater vehicles capable of investigating mine or submarine detection would enhance the responsiveness of the networked capability. Additionally, remote vehicles might constitute the most capable search platform for deeply moored or buried mines.

Once a mine or submarine threat has been detected, classified and located, the threat can be negated or destroyed, as desired by the operational commander and consistent with the extant rules of engagement.

RECOMMENDATION

The Navy needs to proceed to develop an undersea CEC capability.

ANTI-ACCESS AREA DENIAL THREATS IN THE LITTORAL BATTLESPACE

It is already evident that some potential aggressor nations are developing layered defensive and offensive systems to protect their littoral areas from approach by surface, subsurface and air platforms. These layered defenses may extend well over a 1,000 miles from the shoreline and consist of a wide variety of weapons platforms and surveillance systems.

The following table describes potential surveillance systems that can monitor ocean approaches thousands of miles at sea primarily using space-based, all weather, day/night radar imagery and signals intelligence collection.

21st Century Warfare Anti-Access Area Denial Layered Systems	
<i>Potential Layered Weapons Capabilities</i>	<i>Supporting Enemy C3ISR</i>
<ul style="list-style-type: none">• Long-range (1,500-2,000 miles) radar-guided ballistic missiles	<ul style="list-style-type: none">• Commercial space-based EO/IR/radar imagery• One hour availability
<ul style="list-style-type: none">• Diesel submarines equipped with anti-ship cruise missiles and advanced torpedoes	<ul style="list-style-type: none">• Space, sea and land-based SIGINT
	<ul style="list-style-type: none">• Fixed and deployable sonar systems
<ul style="list-style-type: none">• Naval mines - deep water and littoral areas	<ul style="list-style-type: none">• Over-the-horizon, land-based radar systems
<ul style="list-style-type: none">• Surface and subsurface naval forces	<ul style="list-style-type: none">• Naval combat forces including diesel submarines with air independent propulsion
<ul style="list-style-type: none">• Manned and unmanned aircraft	<ul style="list-style-type: none">• Manned and unmanned airborne surveillance
<ul style="list-style-type: none">• Deeply buried or mobile anti-access missile systems fired out of buried facilities	<ul style="list-style-type: none">• Internetted mobile and fixed air and missile defense systems

By 2015, more than a dozen nations are projected to have deployed space-based imagery systems. For those nations without organic space systems, the imagery will be readily available for purchase on the open or black commercial markets. Integration of the many sensor system options should provide correlated knowledge that will make it very difficult to spoof, decoy or evade detection except possibly for modern nuclear submarines and very stealthy air vehicles. In short, it will be extremely difficult to deny a competent enemy some level of warning information.

Surface ships approaching a potential combat zone are likely to be detected at significant ranges from shore even if they employ some level of RF/IR/acoustic signature reduction.

The table also shows potential weapons that might be employed to create a layered defense starting in deep ocean waters. These layered defenses are designed to drastically slow or outright deny access from the air and sea to a littoral area.

A New Anti-Ship Missile Concept

Characteristics

Launcher: Land-based in either covert vertical launch tube or on transporter-loader vehicles

Range: 1,500 to 2,000 miles

Payload: 2,000 pound reentry vehicle with 1,500 pound HE penetrator warhead

Guidance: Ballistic inertial with GLONASS
Inflight updates via satellite datalink

RV RCS: ~30 dbsm

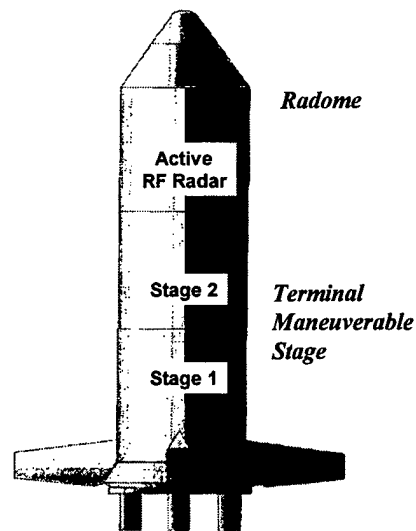
Reentry

Velocity: 13,000 ft/sec

Radar

Terminal

Seeker: Employees ATR and has GMTI capability



The figure above depicts one concept for attacking moving or stationary surface shipping at great ranges in all weather. Such an anti-ship missile could easily be developed by the 2015 time frame. The US in the 1970s developed Pershing II to accurately attack fixed targets using active radar area correlation guidance. More than thirty years later, an improved imaging radar with the added ability to track moving targets is technically feasible. In fact, such a weapon could also be employed to attack fixed or moving tactical targets at great ranges with precision submunitions or hard target penetrators. Targeting data could be derived from a space-based synthetic aperture radar system able to track moving targets. Updated targeting information could be sent to the attacking missile as it flies into the target areas similar to what is planned for Tactical Tomahawk.

Intercept of a missile system as described is extremely difficult because of the combination of a near vertical reentry angle and the high velocity.

RECOMMENDATION

- The US Navy needs to consider a ballistic missile (C4) offensive conventional attack system with multiple warhead options for deployment on surface and sub surface ships.
- The US Navy should examine defensive and offensive options against anti-access, area denial options.

CHAPTER 4.

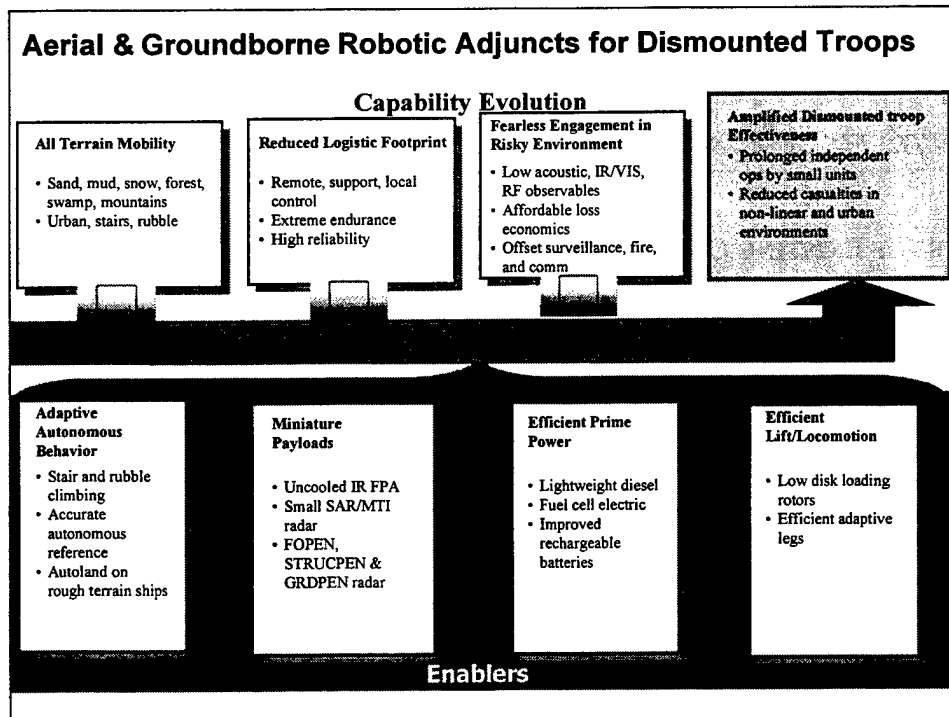
Robotic Adjuncts for Dismounted Troops

CHAPTER 4.

Robotic Adjuncts for Dismounted Troops

In pursuing the Full-Spectrum Dominance envisioned by Joint Vision 2010, heavy emphasis is generally placed on the interactive and synergistic effects of Information Superiority, Dominant Maneuver, Precision Engagement, Focused Logistics, and Full Dimensional Protection. The treatment of these several components elsewhere in this report has generally led to large-system solutions which surround and overwhelm the source of threat or resistance. But another dimension of the 2015 timeframe vision is the need to directly amplify the implicitly “light” ground forces by providing dismounted troops with improved organic means to act and survive in spite of their diluted deployment and exposure to unconventional threats in urban and difficult terrain, particularly in the confusing presence of non-combatants.

The emerging opportunity for this aspect of force-amplification and casualty-reduction takes the form of a family of organic robotic adjuncts (both aerial and groundborne) for use by otherwise dismounted troops. As seen in the figure below, advances in adaptive autonomous behavior, miniature payloads, efficient small scale prime power, and efficient small scale lift/locomotion are converging to enable true all-terrain mobility, reduced forward logistic footprint, and fearless engagement in risky environments. These in turn combine to yield amplified force effectiveness and human casualty reduction for dismounted troops (particularly in isolated or ambiguous operations).



Aerial & Groundborne Robotic Adjuncts for Dismounted Troops

While future (2015) military requirements for a family of robotic adjuncts cannot be firmly specified at this time, it is possible to discuss a family spectrum of currently imaginable operational needs and to postulate foreseeable technical performance capabilities.

On the high end of the organic robot spectrum are those capable of 150-300 kg payloads, (smart aerial utility vehicles or smart mechanical mules) which carry cargo, standoff sensors, light direct fire weapons, and long haul communications and which can provide ground auxiliary power, long endurance loiter, and operability in urban or difficult terrain without trained operators or organic support. These robots, with basic optical and comm payload, should cost no more than \$900K flyaway or \$700K walkaway. In a pinch, these robots can even transport a couple of equipped soldiers.

In the middle of the size spectrum are 10 kg man-portable robots (smart eagle and smart dog) which might carry 1 kg or more payload for more detached missions of a surveillance or demolition nature. These would possess moderate communications (possibly even low data rate SATCOM) and could operate off-tether for extended periods. This size (both ground and airborne) and cost (\$50-75K) might be particularly adaptable to extended sentinel duty in suspected BW/CW environments.

At the smaller end of the size spectrum is the smart pigeon or smart rodent (grossing at only 1 kg with possibly a 100 g payload and approximately \$5K cost). This backpack robot clearly is most suited to visual scouting of threatening environments, including inside buildings, and can be regarded as disposable in difficult circumstances.

Much smaller robots (of the insect and microbe size) are not treated here due to their more purpose-specific missions and their weather susceptibility (wind and rain).

LARGE BATTLEFIELD ROBOTS

DEFICIENCIES OF EXISTING ORGANIC SUPPORT FOR DISMOUNTED TROOPS

Local mobility, standoff surveillance, direct fire support, air defense, communications relay, and ground auxiliary power supply for and in support of dismounted small teams using current ground support vehicles or normal utility helicopters in non-linear battlefield conditions is currently deficient in six respects:

- Terrain dependence – Small ground vehicles can cope with mud, snow and sand, but are strongly deficient in swamp, forest, mountain and urban conditions. Further, their dependence on or preference for roads increases their predictability and vulnerability.
- Speed and range – If close-by ports and airfields are denied (an increasingly probable situation), support ground transport, will become untimely; support by current helo will be beyond operating radius and visible
- Forward logistic footprint – Conventional organic ground vehicles and small helos create unacceptable refueling and maintenance burdens on small combatant forces because their limited range prevents rear basing.

- Survivability – Current local mobility vehicles (both ground and air) pay little attention to signature reduction (visible, IR, RF, active emissions, noise, and dust), which will increase in importance as otherwise sparse opposing forces acquire shoulder-launched precision weapons.
- Economy – The high acquisition and support cost of existing small manned helicopters (and the necessary pilot training) rule out widespread use of current small vertically capable vehicles in support of individual soldier combatants.
- Alternative organic use – Lack of forward controlled, sensor and weapon-equipped aerial platforms prevents small ground forces from applying non-revealing offset direct fire and standoff surveillance. When truly isolated (without AEW or JSTARS), these forces possess neither warning nor standoff defense against air or ground attack.

SMART AERIAL UTILITY VEHICLE

A smart aerial utility vehicle which could close these shortfalls might have the following characteristics as seen in more detail in the following figure:

- Autonomous, remote RF, and voice controlled vertical flight and precision landing to avoid the need for and risk of trained pilots
- Payload of 150-300 kg for optical and RF sensors, covert SATCOM, light weapons and (in an emergency) up to two equipped troops
- ~2-day air endurance, plus ground loiter for extended accompaniment without forward logistic support
- 150 kt speed for rapid long range transit from remote support bases
- >1,000 nm radius for remote sanctuaried basing and 3,000 nm range for self-ferry
- Low acoustic, IR, visible, RF, smoke, and dust signature for survivability
- 5-10 kW for SAR/MTI or AEW radar power or portable ground APU application
- Multi-spectral optics, high data rate SATCOM, low data rate covert SATCOM, ESM, EW, and BC detectors
- Light anti-ground and anti-air weapons
- Small-ship-compatibility for offshore basing
- Affordable cost of <\$900 K flyaway in production.

Such a smart aerial utility vehicle would enable:

- Fearless, untaxing, low signature, distant insertion, reposition, resupply, rapid maneuver, and emergency extraction of dismounted troops, SOF, and agents under non-linear warfare conditions

Aerial Robotic Adjuncts for Dismounted Troops
NOTIONAL FAMILY CHARACTERISTICS

Characteristics	Smart Aerial Utility Vehicle*	Man Portable	
		Smart Eagle	Smart Pigeon
<u>MISSIONS</u>	All-Weather Standoff Sensing, Offset Direct Fire, Comm Relay, CM, Ground Support Aux. Power, Resupply, Emergency Insertion/Extraction, Short Range AEW, Helo Intercept	Over-the-Battlefield, Over-the-Streets, Through-the-Windows Surveillance and Weapon Operations	Over-the-Hill, Around-the-Corner Scouting
Basing and Support	Remote Sanctuaried Support, Organic Deployment	Man Portable, Ground Vehicle Supported	Backpack, Reusable
Launch Techniques	VTOL, Ship-Capable	VTOL	Hand Thrown
Command, Telemetry, and Image Return	Autonomous, Voice, Direct RF, Relay and SATCOM	Autonomous, Direct RF, SATCOM	Autonomous, Direct RF, Direct Optical Return
Gross Mass (OGE, SL, hot day)	~1,500 kg	<10 kg	<1 kg
Airborne Endurance	~2 days	10 hrs	2 hrs
Ground Loiter Endurance	~2 weeks	1 week	N/A
Max. Altitude	~10,000 m	>1,500 m	>1,500 m
Max. Cruise Speed	>150 kts	>50 kts	>40 kts
Operating Radius	>1,000 nm	50 nm	10 nm
Ferry Range	>3,000 nm	200 nm	40 nm
Total Payload	Self Deploy Worldwide		
Flyaway Cost with Minimum Electronic Payload	150-300 kg	~1 kg	100 g
– Minimum Electronics	<\$900K	<\$75K	<\$5K
– Optional Electronics	IR/Vis Optics, High Data Rate (10 Mb/s) Direct and Relay Comm, Covert Low Data Rate (100 kb/s) SATCOM	IR/Vis Optics (1"), Medium Data Rate (1.5 Mb/s) Direct Comm, Very Low Data Rate (1 kb/s) Long Wavelength Comm for Structure & Foliage Penetration	IR/Vis Optics (0.25"), Low Data Rate (100 kb/s) Direct Comm, Very Low Data Rate (1 kb/s) Long Wavelength Receive for Structure & Foliage Penetration
– Other Payload	MTI/SAR, FOPEN, STRUCPEN, GRDPEN, Mine Detection Radar; ESM, EW, BC Detector, Wideband (10 Mb/s) SATCOM	MTI/SAR Radar, ESM, EW, BC Detector; Seismic, Magnetic, Acoustic Sensors; Narrowband (1 kb/s) SATCOM	BC Detector, Acoustic Sensor
– Other Payload	Cargo, Weapons, Personnel, Remote Deployed Devices	Demolitions, UGS Placement and Retrieval	Tags, Disablers
Payload or APU Draw Power	5-10 kW	100 W	10 W
Signature Reduction	Acoustic, IR, Visible, Smoke, Dust	Acoustic, Smoke	Acoustic, Smoke

* Note: Same vehicle also suitable for naval missions such as ASW and ship-organic mine detection.

- Elevated and physically offset all-weather ground surveillance, comm relay, and direct fire to prevent revelation of ground force position
- short range air surveillance against cruise, ballistic, and helo attack
- Remote emplacement/retrieval of UGS or other specialized devices

To achieve the needed performance will likely require the development of:

- Fuel efficient, lightweight, heavy fuel engines in the 200-300 shp size for long endurance and field/ship logistic fuel compatibility
- Low disk loading, lightweight rotors for low noise, extremely efficient flight
- Automatic flight control and composite rigid rotors for precision take off/land in turbulence and to handle ship motion

The most stressing developments and hence largest uncertainties are expected to be:

- Vibration at high speed
- Rotor hub reliability and cost
- Signature reduction, particularly acoustic

SMART MECHANICAL MULE

Like its aerial counterpart, the smart mechanical mule might have the following characteristics as seen in the figure on page 74.

- Autonomous, remote RF, and voice controlled behavior to avoid tying up a dedicated human handler
- Payload of 150-300 kg for optical and RF sensors, covert SATCOM, light weapons and (in an emergency) up to two equipped troops
- Lengthy endurance (2 weeks) for extended accompaniment without forward logistic support
- 1,000 km radius at 20 km/hr for remote sanctuaried basing
- Low acoustic, IR, visible, smoke and dust signature for survivability
- 2-5 kW for MTI, FOPEN, STRUCPEN, GRDPEN radar or portable ground APU application (though at lesser ranges than the airborne counterpart)
- Multi-spectral optics, high data rate SATCOM, low data rate covert SATCOM, ESM, EW, and BC detectors
- Light weapons

Ground Robotic Adjuncts for Dismounted Troops

NOTIONAL FAMILY CHARACTERISTICS

Characteristics	Man Accompanying Smart Mule	Man Portable, Reusable	
		Smart Dog	Smart Rodent
MISSIONS	All-Weather Standoff Sensing, Offset Direct Fire, Comm Relay, Ground Support Aux. Power, Resupply, Emergency Insertion/Extraction	Around-the-Mountain, Through-the-Forest, Through-the-City Surveillance and Weapon Operations	Around-the-Corner, Inside-the-Building Scouting; Stealthy Sentinel
Basing and Support	Remote Sanctuaried Support, Organic Deployable	Man Portable, Ground Vehicle Supportable	Backpack, Reusable
Command, Telemetry, and Image Return	Autonomous, Voice, Direct RF, Relay, and SATCOM	Autonomous, Direct RF, SATCOM	Autonomous, Direct RF, Direct Optical Return
Gross Mass	~600 kg	<10 kg	<1 kg
Loiter Endurance	2 weeks	1 week	1 day
Dash Speed	40 km/hr	10 km/hr	10 km/hr
Cross Country Speed	20 km/hr	5 km/hr	5 km/hr
Range on Flat Ground	2,000 km	500 km	100 km
Agility	100% Grade, Stairs, Rubble	100% Grade, Stairs, Rubble	100% Grade, Stairs, Rubble
Terrain Coping	Mud, Snow, Sand, Swamp, Forest, Mountain, Urban	Mud, Snow, Sand, Forest, Mountain, Urban	Mud, Sand, Forest, Mountain, Urban
Total Payload	150-300 kg	1-5 kg	100-500 g
Walkaway Cost with Minimum Electronic Payload	<\$700K	<\$50K	<\$5K
– Minimum Electronics	IR/Vis Optics (5"), High Data Rate (10 Mb/s) Direct and Relay Comm, Covert Low Data Rate (100 kb/s) SATCOM	IR/Vis Optics (1"), Medium Data Rate (1.5 Mb/s) Direct Comm, Very Low Data Rate (1 kb/s) Long Wavelength Comm for Structure & Foliage Penetration	IR/Vis Optics (0.25"), Low Data Rate (100 kb/s) Direct Comm, Very Low Data Rate (1 kb/s) Long Wavelength Receive for Structure & Foliage Presentation
– Optional Electronics	MTI, FOPEN, STRUCPEN, GRDPEN, Mine Detection Radar; ESM, EW, BC Detector, Wideband (10 Mb/s) SATCOM	MTI Radar, ESM, EW, BC Detector; Seismic, Magnetic, Acoustic Sensors; Narrowband (1 kb/s) SATCOM	BC Detector; Seismic, Magnetic, Acoustic Sensors
– Other Payload	Cargo, Weapons, Personnel	Demolitions, UGS Placement and Retrieval	Tags, Disablers
Payload or APU Draw Power	2-5 kW	100 W	10 W
Signature Reduction	IR, Visible, Acoustic, Smoke, Dust	IR, Visible, Acoustic, Smoke, Dust	IR, Visible, Acoustic, Dust

- Mobility in mud, snow, sand, swamp, forest, mountain, and urban terrain and agility on rubble and stairs
- Affordable cost of <\$700 K walkaway in production.

Such a smart mechanical mule would enable:

- Untaxing, low signature, distant accompaniment; cargo carrying support; and emergency extraction of wounded or fatigued troops
- Physically offset, all-weather ground surveillance, comm relay, and direct fire to prevent revelation of troop ground position
- Low risk minefield breaching and clearance
- Remote emplacement/retrieval of UGS or other specialized devices
- Fearless urban warfare operations

To achieve the needed performance will likely require development of:

- Efficient, adaptive, legged locomotion in difficult and complex terrain and confined quarters
- Fuel efficient, lightweight fuel cell prime power for propulsion and payload
- Autonomous navigation among natural and man-made obstacles and within buildings
- Through-wall sensors and low data rate communications

The most stressing development and hence largest uncertainty is expected in the area of small, low power draw, ground-, structure-, and foliage-penetrating sensors and communications.

MEDIUM BATTLEFIELD ROBOTS

The large battlefield robots treated above are sized to amplify the load carrying capacity of dismounted troops without imposing the forward logistic burdens and dexterity limitations of traditional short range organic wheeled vehicles and small helicopters. But the medium-sized robots treated in this section are sized by the desire to obtain as much functional capability as possible within a man-portable, fully fueled assemblage (nominally 10 kg gross weight with fixed electronic payload). In that light, two notional medium-sized robots (aerial and groundborne) are sketched out to illustrate a possible future capability, matching desirable operational capabilities with credible technology projections based on embryonic DARPA and Service programs.

SMART EAGLE

A smart aerial robot of the 10 kg gross weight variety might have the following characteristics as seen in more detail in the figure on page 72:

- Man-portable, ground vehicle supportable, autonomous vertical flight, hover, and precision landing
- High data rate line-of-sight RF comm, low data rate SATCOM, through-the-wall comm, and voice controlled command
- Payload of ~1 kg for day/night optics and comm, with added optional MTI/SAR, ESM, EW, BC detectors; seismic, magnetic, acoustic sensors; and demolitions
- 10 hr airborne endurance; one week ground loiter
- 50 kt cruise speed; 200 nm range; 50 nm normal maximum operating radius
- Affordable cost of <\$75K flyaway in production.

Such a smart aerial vehicle would enable:

- Over-the-battlefield, over-the-streets, through-the-windows, on-the-rooftops surveillance and weapon operations
- Surreptitious placement and retrieval of UGS and demolitions

To achieve the needed performance will likely require the development of:

- Fuel efficient, lightweight, logistically practical prime power in the 5-10 shp size
- Low disk loading, lightweight rigid rotors for low noise efficient flight
- Autonomous precision flight control
- Modest size, low power draw sensors and communications payloads

The most stressing developments and hence largest uncertainties are expected to be in autonomous precision hover in turbulence close to structures and autonomous landing on rough or foliated terrain.

SMART DOG

Like its airborne counterpart the medium-sized robot should be around 10 kg gross weight with basic electronic payload. Capabilities are similar to the airborne variant except that payloads can be upped for certain classes of short duration mission (e.g., ordnance placement) and terrain negotiation dexterity is substituted for flight capability. A notional version is characterized as follows and shown in the figure on page 74:

- Man-portable, ground vehicle supportable, autonomous operation

- High data rate line-of-sight RF comm, low data rate SATCOM, through-the-wall comm, and voice controlled command
- Normal payloads of ~1 kg for day/night optics and comm with added optional MTI radar, ESM, EW, BC detectors; seismic, magnetic, acoustic sensors; and <5 kg demolitions
- One week loiter endurance; 5 km/hr cross country speed, 10 km/hr dash; 500 km range
- Agility in mud, snow, sand, forest, mountain, urban rubble and stairs
- Affordable cost <\$50 K walkaway in production.

Such a smart groundborne ambler would enable:

- Around-the-mountain, through the forest, through-the-city surveillance and weapon operations
- Surreptitious placement and retrieval of UGS and demolitions

To achieve the needed performance will likely require the development of:

- Efficient, adaptive, legged locomotion in difficult and complex terrain
- Fuel efficient, lightweight, logistically practical, prime power for propulsion and payload
- Autonomous navigation among natural and manmade obstacles and within buildings
- Modest size and power draw sensors and communications payloads

The most stressing developments and hence largest uncertainties are expected to be in the area of autonomous interpretation of multiple-gathered and shared perspectives of complex scenes.

SMALL BATTLEFIELD ROBOTS

While the medium-sized robots described above are configured to pack the maximum functional capability into a man-portable assemblage (<10 kg), the small robotic adjuncts (lighter by at least a factor of ten [<1 kg]) are sized to provide a broadly usable functionality in the smallest possible package, while maintaining a reasonably dexterous mobility in mud, sand, and urban terrain.

Two such notional small-sized robots (aerial and groundborne) are postulated to illustrate a possible future capability, matching desirable operational capabilities with credible technology projections based on early-stage DARPA and Service programs. Again, insect and microbe-scale robots are considered too mission-specific and weather-sensitive to provide broad usability

as an adjunct to dismounted troops; hence they are reserved for other mission purposes in different technology programs and are not treated here.

SMART PIGEON

A minimalist smart aerial robot of the <1 kg gross weight variety might have the following characteristics as seen in more detail in the figure on page 72:

- Man-portable, backpack compatible, refuelable/rechargeable, autonomous vertical flight, hover, and precision landing
- Low data rate (100 kb/s) normal direct communications, very low data rate (1 kb/s) long wavelength receive through structures and foliage
- Payload of <100 g for small day/night optics and comm with added optional BC and acoustic sensors, and tags and/or disablers
- Two hour airborne loiter; 10 hr ground loiter
- 40 kt cruise; 40 nm range; 10 nm normal operating radius
- Affordable (possibly expendable) cost <\$5K flyaway in production.

Such a smart aerial vehicle would enable:

- Over-the-hill, around-the-corner, inside building scouting
- Surreptitious surveillance
- BC environment investigation
- Highly specific tagging and disablement

To achieve the needed performance will likely require development of:

- Efficient, high power density, compact prime power in the 0.5-1.0 shp range
- Efficient, low Reynolds number, vertical lift
- Miniaturized, low power draw day/night sensors and communications payloads (<100 g)

The most stressing developments and hence largest uncertainties are expected to be in:

- Autonomous precision control inside buildings
- Landing in rough or foliated terrain
- Low power draw, miniature communications

SMART RODENT

Like its airborne counterpart the small-sized ground robot should weigh <1 kg with basic electronic payload. Capabilities are similar to the airborne variant except that payloads can be increased for short duration missions (e.g., tag placement), and terrain negotiation dexterity is substituted for flight capability. A notional version is characterized as follows and shown in the figure on page 74:

- Man-portable, backpack compatible, refuelable/rechargeable, autonomous operation
- Low data rate (100 kb/s) normal direct communications, very low data rate (1 kb/s) long wavelength receive through structures and foliage
- Electronic payload of <100 g for small day/night optics and comm with added optional BC and acoustic sensors, and tags and/or disablers
- One day loiter endurance; 5 km/hr cross country speed, 10 km/hr dash; 100 km range
- Agility in mud, sand, mountain, urban rubble, and stairs
- Affordable (possibly expendable) cost <\$5K walkaway in production.

Such smart groundborne amblers would enable:

- Around-the-corner, inside-the-building scouting
- Surreptitious surveillance
- BC environment investigation
- Highly specific tagging and disablement

To achieve the needed performance will likely require development of:

- Efficient, high power density, compact prime power/energy in the 0.5-1.0 shp range
- Efficient, adaptive, legged locomotion in difficult and complex terrain
- Miniaturized autonomous navigation among natural and manmade obstacles and within buildings
- Miniaturized, low power draw day/night sensors and communications payloads (<100 g)

The most stressing developments and hence largest uncertainties are expected in:

- Efficient mobility in difficult terrain at such small robot scale size
- Low power draw miniature communications

CONCLUSIONS

The complete postulated family of three aerial and three groundborne notional robots look to be within the foreseeable technology horizon of <15 years. Some are doable within the very near term (prototypes within 3-5 years).

Promising embryonic examples are already underway in DARPA, Service, NASA, university, and commercial programs. Four of the six points of the robot constellation for dismounted troops are currently being addressed within DARPA:

- Smart airborne utility vehicle (Hummingbird Warrior)
- Smart dog (Tactical Mobile Robotics)
- Smart rabbit (Tactical Mobile Robotics)
- Smart pigeon (Micro Air Vehicle)

Other work is scattered, mostly proof-of-principle, and limited in funding.

A few ad hoc narrowly defined service field tests (particularly SOF sponsored) have occurred, but no formalized continuous service-wide sponsored program is apparent for the full spectrum of robotic adjuncts for dismounted troops. Further, no out-year POM money is visible. This lack of non-SOF Service pull in both test programs and budgets is inhibiting serious developers from competing on the few program offerings that have surfaced.

The biggest gaps in the overall technology mix remain in the following functionalities:

- Adaptive autonomous behavior in complex terrain and close quarters
- Efficient vertical and hovering flight in the very low Reynolds number regime
- Efficient adaptive legged locomotion in complex terrain and urban confines

The high payoff of these systems for amplification of dismounted troops (particularly in the increasingly important military missions involving urban warfare, peacekeeping and other ground-intensive operations which are confounded by large numbers of non-combats) suggests the need for increased emphasis (funding), more orchestration among developers and users, and more complete system outputs to allow field experiments.

RECOMMENDATIONS

1. Formalize a Service-sponsored Test/Trials program: Recommend Marine Corps Warfighting Lab (MCWL) of Marine Corps Combat Development Command (MCCDC) as lead to evolve the requirements, explore new operational concepts thereby enabled, and build user confidence.
2. Start a funding wedge in the latter part of the POM to support transitions of successful robotic solutions, prove Services' seriousness, and attract serious developers.

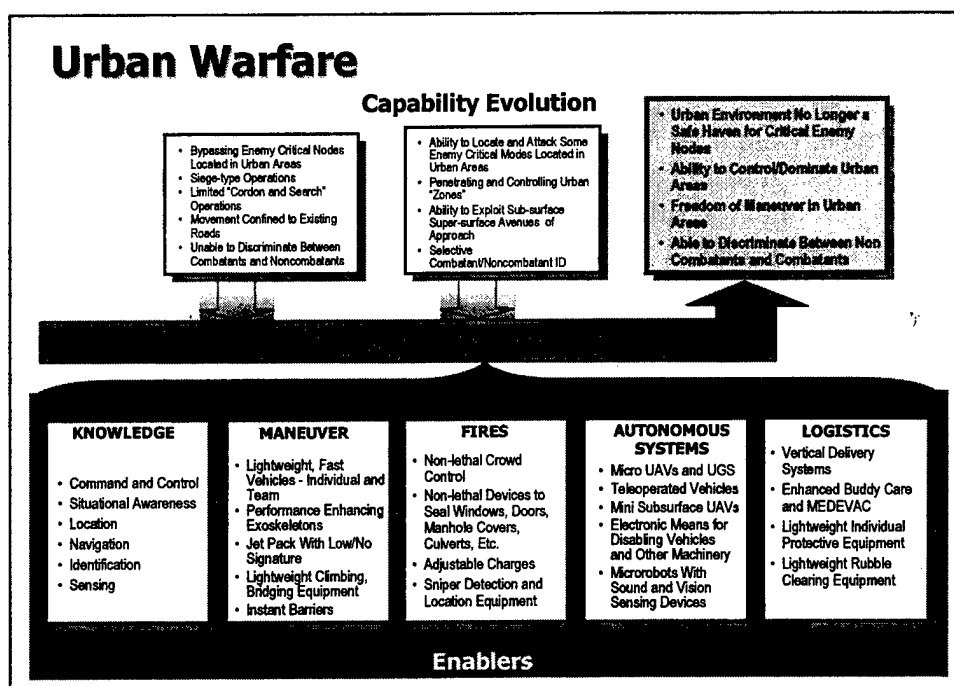
CHAPTER 5.

Urban Operations

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Urban Operations

Urban areas have proven to be a locus for US military intervention in the post cold war period. American forces have conducted major operations in Panama City, Port-Au-Prince, and Mogadishu, and noncombatant evacuation operations in Tirana, Kinshasa, Monrovia, and Freetown. The tide of expanding urbanization in the developing world has increased the likelihood that US forces will again be called upon to operate in urban areas. The evolution of urban warfare capabilities, as shown in the figure below, and the associated enabling technologies – in the five areas of knowledge, maneuver, fires, autonomous systems, and logistics – address the challenges posed by urban warfare. Volume I contains an overview of urban warfare operations. This chapter describes the five enablers in further detail.



Military operations in urban terrain (MOUT) presents unique battlefield characteristics for military forces. Urban environs generate distinct asymmetric advantages for US adversaries, but it may become an increasingly common context in future conflicts. An opponent who chooses to fight in cities selects a combat environment where force requirements and capabilities are different than in other major theaters. Traditional US strengths such as firepower and tactical mobility are negated by the characteristics of urban terrain. Such a context can limit the effectiveness of high technology weaponry and C2I systems, as well as possibly inflict higher rates of casualties and collateral damage.

By their nature as focal points of population, commerce, and government, cities are likely points of interface between US interests and the interests of foreign governments or non-state entities. According to United Nations estimates, the urban population of developing countries

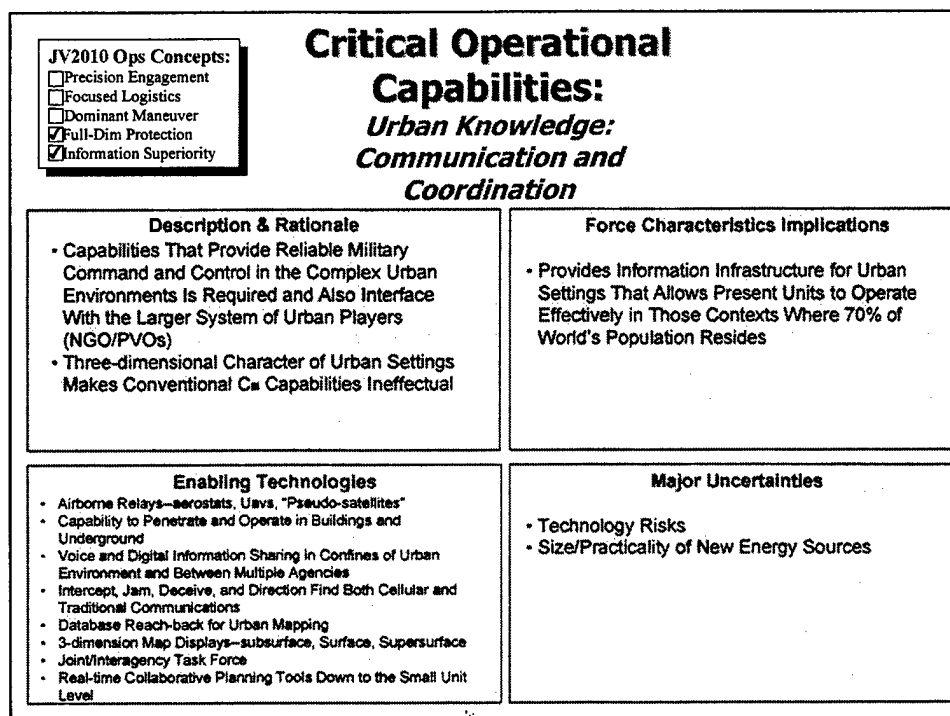
worldwide increases by about 150,000 people each day, with the most pronounced growth occurring in Africa and Asia. By the year 2025, three-fifths of the world's population – five billion people – will live in urban areas. As cities become physically larger and more populous, urban terrain grows more complex. Buildings increase in number, as well as in size. Road networks become more extensive, to include heavy-duty, multi-lane highway systems. Subterranean infrastructure expands as subways and storm sewers reach out to service broader areas.

In some developing nations, the pace of urban population growth may exceed the development of city services. Housing, water, and jobs will be in short supply, giving rise to poverty, disease and crime. Over-crowded conditions will create an environment of social and economic tension which might eventually find an outlet in the form of violence.

Added to the friction, uncertainty, fluidity and disorder which characterize war, the demands peculiar to the urban environment are especially challenging. Urban terrain is an extraordinarily intricate blend of horizontal, vertical, interior, and exterior forms superimposed upon the landscape's natural relief, drainage, and vegetation. The average city includes many styles of construction using a multitude of different building materials, each with its own texture and strength. Urban terrain influences the conduct of military operations to a greater degree than does any other terrain type. Unique to MOUT is the phenomenon that the conduct of operations can radically alter the physical nature of the terrain in ways and to an extent not experienced in other environments. Some buildings suffer damage, with collapsed walls or roofs, while others are razed completely, leaving only a pile of rubble. These effects can be militarily significant, as some key terrain features disappear altogether and fields of fire open and close presenting fleet targets or extremely close combat situations.

Urban terrain is highly restrictive, limiting observation distances, engagement ranges, weapons effectiveness, and mobility. These factors tend to force extremely close combat with troops fighting from building to building and from room to room. Command and control is difficult, because small unit leaders cannot see their troops and radio communication is subject to interference caused by the presence of structures. Historically, urban combat has called for a high degree of initiative by small unit leaders operating with near-autonomy.

In the future, the urban environment will present US forces with situations requiring the conduct of many different categories of military activities. Humanitarian assistance operations, peace operations, and full-scale, high-intensity combat may occur simultaneously in different neighborhoods. Integrating and coordinating these varying evolutions, each of which has its own peculiarities, will challenge US forces to use their skill and determination in innovative and imaginative ways. The presence of large numbers of noncombatants and the potential difficulty in distinguishing these noncombatants from hostile forces will further complicate the task of operating in the urban environment.



DESCRIPTION AND RATIONALE

Key capabilities that are needed to enhance joint military operations in an urban environment – called “Urban Knowledge” – offer enhancements in communication and coordination; location, identification, and sensing tools; and navigation systems. Technology can significantly improve the ability of US forces to capture “urban knowledge” by developing: systems and capabilities that provide reliable military command and control in the urban environment; command and control systems that can interface with the larger system of urban players (e.g., NGO/PVO); the ability to locate, identify, discriminate, and sense friendly enemy and noncombatants in an urban environment; and provide a reliable system to navigate in the multidimensional urban environment.

ENABLING TECHNOLOGIES

Technologies must emphasize the development of adaptive, relevant command and control systems to operate in the urban environment. Technological developments that could enhance communication and coordination in urban areas include:

- **Airborne communication relays.** Buildings blocking line of sight transmissions and areas in which electromagnetics interfere with radio transmissions and receptions compound communication difficulties in the urban environment. Aerostat-type

tethered balloons, unmanned aerial vehicles, and 'pseudo-satellites' are some possible solutions for overcoming this challenge.

- ***Diverse communications capability.*** Military members can expect to operate inside buildings and in the subterranean environment. Communications capabilities need to be developed that can penetrate the ground and into heavy urban structures.
- ***Voice and digital information sharing.*** In urban environments, it is likely that US forces will need to share information and coordinate activities with a myriad of non-military organizations. Methods need to be developed to enable rapid information exchange between military and non-military agencies, while providing the commander with the ability to safeguard the designated information.
- ***Conduct electronic warfare operations.*** Friendly forces can gain tempo by exploiting enemy communications. In the urban environment, US forces can expect that belligerents will use multiple methods for communicating—including cellular communications. To fully exploit this medium, US forces need the capability to intercept, jam, deceive, and direction find both cellular and traditional communications in the urban environment.
- ***Reachback capability for mapping and navigation.*** Units should have the ability to reach back or reach forward to receive current, relevant information on the infrastructure of a particular urban setting. The data base that maintains this information should include accurate maps depicting roads, underground infrastructure (e.g., sewer systems, subways), and floor plans/engineering diagrams for buildings.
- ***3-dimensional mapping capability.*** Troops operating in the urban environment will need to know their precise location and the location of their target in three dimensions and in surface, subsurface, and supersurface locations.
- ***Real-time collaborative planning tools.*** Command and control activities in the urban environment are made more complex by the difficulties of communication and movement within the urban terrain. Control will likely be decentralized to small unit leaders. Collaborative planning tools able to pass information to the small unit leader would add enhanced meaning to mission-type orders and provide commanders with the ability to graphically depict commander's intent.
- ***Joint Interagency Task Force.*** Response of future threats will often require more than a military response. This is especially true in urban environments where humanitarian and peace operations may be occurring simultaneously. The extensive breadth of relevant knowledge and skills in other government organizations, non-governmental organizations, and private organizations should be leveraged to help gain information and knowledge on the enemy. The ability to integrate these myriad activities could become an asymmetric advantage for US and coalition forces. It could also enhance abilities to anticipate crises, as well as respond. Technologies that could better enable coordination and cooperation between the military and other organizations include: the living internet; multimedia information exchange tools; collaborative planning tools; portable wireless communications; and a reach back, forward, and out communication capability and architecture.

The ability to command and control in the urban environment also includes the need to gain battlespace awareness. As part of that effort, US forces must be able to locate, identify, and sense enemies and noncombatants in urban terrain. Technologies that could assist in this process include:

- **Combat Identification.** Friendly troops and vehicles must be identified as such and be tagged with an identification tracker/device to negate fratricide. Likewise, tagging should also occur for known noncombatants and belligerents.
- **Ability to “see through walls.”** Urban terrain compounds the problem of locating enemy forces/belligerents in the urban environment. Forces operating in the urban environment will need to have the tools to “see” through walls, ceilings, and floors in order to locate and target belligerents.
- **Microbots.** Micro-robots equipped with sound and visual sensing devices could be used to scout buildings, sewers, and other areas; provide in-place reconnaissance of areas; and track belligerents within the urban environment. The small size of the microbots would make them stealthy.
- **Micro-UAVs.** Similar to the microbots, micro-sized UAVs could be used to reconnoiter large areas and track the movement of enemy forces with little chance of detection.

Navigation within the urban environment is a complex procedure. New construction or destruction often makes existing maps and charts unreliable. Also, US forces will have a requirement to operate in several media—surface, subsurface, and supersurface—to effectively maneuver through urban areas. Within the urban canyons, distinguishing landmarks are often lost with navigation by dead reckoning unachievable. Global positioning data can be masked by tall obstructions and often is not precise enough to provide the needed information. Technologies that can facilitate navigation within the urban environment include:

- **3-dimensional position location.** Troops operating in the urban environment will need to know their precise location and the location of their target in three dimensions and in surface, subsurface, and supersurface locations.
- **Reachback capability for mapping and navigation.** Units should have the ability to reach back or reach forward to receive current, relevant information on the infrastructure of a particular urban setting. The data base that maintains this information should include accurate maps depicting roads, underground infrastructure (e.g., sewer systems, subways), and floor plans/engineering diagrams for buildings.

FORCE CHARACTERISTICS IMPLICATIONS

The granularity of urban terrain and the presence of noncombatants will combine to create friction that can potentially erode the effectiveness of basic operational capabilities. DoD needs to begin to explore means for enhancing capabilities so as to overcome this erosion.

Command and control systems need to readily adapt to operations in urban terrain. Communication devices should be able to function in multidimensional urban surroundings,

ensuring reliable communications between structures, streets, and sewers. Under circumstances in which unit boundaries will most likely include a vertical component in addition to the traditional horizontal limits, commanders need a mechanism for identifying appropriate features and expressing plans to subordinates in three-dimensional terms.

The restrictions urban terrain imposes upon the ability of unit leaders to monitor and direct the activities of subordinates needs to be overcome. US forces need to be able to determine and report locations in three-dimensional terms, with sufficient precision to identify individual rooms in a building, or even specific locations within rooms. Command and control mechanisms need to display three-dimensional terrain in formats which enhance understanding and provide the user a "feel" for the ground. Computer-generated map products will provide a graphic representation of urban terrain, reflecting in near-real time changes caused by combat action (e.g., collapsed structures, and flooded subways). Such products will be data-intensive; command and control hardware must be capable of retrieving, exchanging, storing, displaying, and manipulating these data in large quantities and at a very-small unit level.

Despite advances in technology, future MOUT will remain clouded by the fog and friction of war. Commander's intent, mission tactics, and implicit communications will remain fundamental to achieving the application of maneuver warfare to the urban environment. Command and control procedures and systems need to be flexible, adaptive, and decentralized to account for the uncertainty inherent in combat.

Urban terrain will provide superb concealment for units occupying or moving through structures, subways, sewers, alleys, or narrow streets. Not only will this characteristic increase the difficulty of detecting the enemy, but it will also render command and control efforts more challenging by screening friendly units from their commanders' observation.

"Awareness" is the ability of an individual US military member or a unit to sense the battlespace and to accurately assess information regarding the terrain and the presence of friendly, enemy, and noncombatant personnel. Enhanced awareness will allow US forces in a built-up area to gather information despite the presence of masking terrain features. A particularly challenging aspect of urban terrain is the fact that much of the "volume" of a major city is actually interior—the space found inside structures or under the ground. US forces need the capability to "sense through walls" and to detect the presence and shape of tunnels and sewers. Sensors should provide for 3-dimensional interior rendering, with the capability to display, store, and transfer information between units. For example, a patrol operating at surface level should be able to identify and report the extent and shape of the subways and sewers running under their patrol route at the sub-surface level. Other systems should provide a capability for remote interior sensing, perhaps using equipment mounted on aircraft.

MAJOR UNCERTAINTIES

Major uncertainties for these capabilities include a range of technology risks, system integration at the lowest tactical levels, and the size and feasibility of new, smaller power sources. Among the technology risks are the development of microrobotics that meet the need of the military and overcome the physics of wireless communications through buildings and underground. System integration will be extremely difficult at the lowest tactical levels. A high demand will be placed on the amount of information that will need to be available to small unit

leaders, and the military is looking to technology to answer that challenge. Finally, technologies in miniaturized robots and UAVs will require miniature power sources able to provide unprecedented levels of power on which these devices will need to operate.

Discovering and exploiting other than military applications for the technology can mitigate some of these uncertainties. For example, the ability to provide precision location in three dimensions would also be useful to firefighters. Encouraging industry to develop new energy sources may also prove profitable in the civilian sector.

JV2010 Ops Concepts: <input type="checkbox"/> Precision Engagement <input type="checkbox"/> Focused Logistics <input type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>Urban Knowledge: Location, Identification, and Sensing</i>		
Description & Rationale <ul style="list-style-type: none"> • Capability to Locate, Identify, Discriminate and Sense Friendly, Enemy and Noncombatants in Complex Urban Environment Is Required • Present Systems and Processes Are of Limited Utility, and of Questionable Value, While Exposing Friendly Forces to Great Risk 	Force Characteristics Implications <ul style="list-style-type: none"> • Significantly Empowers Small Units, Giving Them Detailed Situational Awareness of Densely Populated Context and in Multi-story Structures 		
Enabling Technologies <ul style="list-style-type: none"> • CID for Both Troops and Vehicles • Ability to Discriminate Between Combatants and Noncombatants—tagging or Individual Sensors • Multispectral Vision Devices to See Through Walls, Ceilings, Floors • Micro-robots w/Sound & Vision Sensing Devices • Small "Micro" UAVs 	Major Uncertainties <ul style="list-style-type: none"> • Technology Risks • Size/Practicality of New Energy Sources 		

Technologies for Urban Knowledge: Location, Identification and Sensing

There is a requirement to locate, identify, sense, and discriminate friendly, enemy, and non-combatants in the complex urban environment. Current systems and processes are of limited utility, and of questionable value, while exposing friendly forces to great risk. Moreover, the three-dimensional character of the urban landscape makes traditional and conventional C² capabilities largely ineffective.

A family of new and adaptive location, identification and sensing devices must be developed in order to overcome the challenges that the urban environment presents:

- **Combat identification (CID)** for troops, vehicles and equipment.
- **"Tagging" or individual sensors** to discriminate between combatants and non-combatants.
- **Multi-spectral vision devices** to see through walls, ceilings, floors, etc.
- **Micro-robots** with sound and vision sensing devices.
- Small "micro-electro-mechanical systems" (**MEMS**) **unmanned aerial vehicles**

JV2010 Ops Concepts:

- ☐ Precision Engagement
- ☐ Focused Logistics
- ☐ Dominant Maneuver
- ☒ Full-Dim Protection
- ☒ Information Superiority

Critical Operational Capabilities: Urban Knowledge: Navigation

Description & Rationale

- Provide Ability to Reliably Navigate in Strange, Complex Multi-dimensional Urban Environments That Include Subsurface, Surface, Supersurface, and Air Avenues of Approach
- A New Generation of Physical Knowledge Is Required in Urban Situations Which Includes Elevation and Interior Space Information As Well As Basic Terrain

Force Characteristics Implications

- Provides Situational Awareness That Allows Small Units to Reliably Navigate in Three Dimensional Urban Space

Enabling Technologies

- 3-Dimensional Mapping--subsurface, Surface, Supersurface
- 3-Dimensional Position Location
- Reach-back Capability to National and NGO/PVO Databases

Major Uncertainties

- Technology Risks
- Size/Practicality of New Energy Sources

Technologies for Urban Knowledge: Navigation

There is a requirement to reliably navigate in strange, complex, multi-dimensional urban environments that include subsurface, surface, supersurface and air avenues of approach. A new dimension of knowledge is required in urban environments which include elevation and interior space dimensions in addition to basic terrain. Currently, the three-dimensional character of the urban landscape makes traditional and conventional navigational techniques largely ineffective.

A family of new and adaptive navigation techniques and devices must be developed in order to overcome the challenges that the urban environment presents:

- **Three -dimensional mapping**--surface, subsurface and supersurface in real time/near real time to capture the changing environment of urban areas
- **Three-dimensional position location**
- **Reach-back capability** to national and NGO/PVO mapping and location databases
- **Individual sensing equipment/devices**

URBAN MANEUVER

JV2010 Ops Concepts:

- ☐ Focused Logistics
- ☐ Information Superiority

Critical Operational Capabilities: ***Urban Warfare: Maneuver***

Description & Rationale

- Ability to Move and Maneuver Combat Power Through the Multi-dimensional Urban Environment
 - Movement Between Multi-Floor/High-Rise Structures.
 - Movement on Exterior and Interior of Buildings Without Using Existing Stairs, Ladders, or Elevators for Standard Infantry Units.
 - Rapid, Individual Movement Within Urban Environment
 - Vertical Insertion/Extraction Devices to Support Helo Operations
 - Subsurface Movement

Force Characteristics Implications

- Small Unit Mobility--Decentralized Execution
- Specialized Training in Urban Mobility and Navigation

Enabling Technologies

- Lightweight Breaching/Bridging Capability to Allow Crossing Urban Canyons--Rooftop-to-Rooftop and Intermediate Floor to Intermediate Floor Crossing Capability.
- Jet Packs With Low/No Noise Signature.
- Performance Enhancing Exoskeletons.
- Individual All-terrain Vehicles.
- Lightweight, Air-Transportable, Quick Acceleration Pickup Truck-like Vehicles.
- Reachback Capability for Mapping/Navigation

Major Uncertainties

- Technology Risks
- Motivation for Commercial Development
- Affordability/Funding

DESCRIPTION AND RATIONALE

Technology can significantly enhance the US military's ability to move and maneuver within the urban environment. Challenges that technology can help US forces overcome include: movement between multi-floor/high rise structures; movement on the exterior and interior of buildings without using existing stairs, ladders, or elevators; rapid, individual movement; vertical insertion and extraction using helicopters; and movement in the subterranean environment.

ENABLING TECHNOLOGIES

Technologies must emphasize the development of enablers to allow US forces to maneuver multidimensionally within the confines of the urban environment. Some technologies that can enhance multidimensional maneuver include:

- ***Lightweight breaching/bridging capability.*** This capability would allow forces to cross urban canyons without returning to the street level. Lightweight bridges would be used for individual/unit movement from rooftop-to-rooftop and intermediate floor-to-intermediate floor movement, allowing troops to avoid the potential danger areas of existing stairs, ladders, and elevators.
- ***Low noise jet packs.*** The jet packs would allow 3-dimensional movement within the urban canyon, facilitating reconnaissance in, around, and above urban superstructures.
- ***Lightweight, man-portable ladders.*** The addition of this technology would allow movement between floors both on the interior and exterior of buildings and in subterranean environments without the use of existing stairs, ladders, or elevators.
- ***Advancements in vertical insertion and extraction.*** Helicopter insertion/extraction of troops is likely in an urban scenario. Technologies that can enhance this capability include equipment that can test the strength of a roof and devices that allow offset rappelling from a helicopter (or rooftop) to a lower location.

Belligerents will make optimum use of the cover and concealment afforded by the urban terrain. Individuals must be able to move quickly in the urban environment to minimize exposure to fire. Technologies that could assist in this area include:

- ***Performance enhancing exoskeletons.*** Exoskeletons could assist friendly troops in maneuvering both over obstacles and in open terrain. By adding additional strength and stamina to the individual troop, the exoskeleton would allow the individual to move faster and carry greater weights than when operating without the device.
- ***Individual all-terrain vehicles.*** Urbanized all-terrain vehicles would also assist in rapid movement through urban canyons, increasing the speed at which individuals can maneuver, while minimizing their footprint. Small vehicles of this type could be moved to and from the objective internal to helicopters or tilt-rotor aircraft.
- ***Lightweight, air-transportable vehicles.*** Scaled-down pick-up truck-like vehicles would also be extremely beneficial to enhancing maneuver in the urban environment.

The small vehicles could carry both troops and equipment, yet reduce the logistic footprint significantly. The ability for deployment internal to helicopters and tilt-rotor aircraft is a necessity to enhance movement to and from the objective.

The ability to outmaneuver one's opponent, whether in urban terrain or open spaces, should be measured in relative terms to the opponent's ability to maneuver. Therefore, countermobility will play a significant role in allowing friendly forces to gain tempo in the modern battlespace. Within the urban environment, countermobility enhancements could include:

- **Barriers.** Friendly forces should have the ability to rapidly erect barriers using material readily available in the urban environment – such as rubble – to channelize enemy forces or deny enemy movement into and out of areas..
- ***Man/vehicle portable devices to seal windows, doors, manhole covers, culverts, and other portals for entering or exiting buildings.*** Technologies in this area will allow forces to secure buildings and subterranean accesses without physically entering the structure or causing large amounts of collateral damage. This technology also enhances force protection.

FORCE CHARACTERISTICS IMPLICATIONS

The freedom to conduct movement within and between the surface, subsurface, and supersurface areas that characterize the urban environment will be critical to the ability to adapt maneuver warfare to the urban environment. US military members units will need enhanced mobility characteristics to facilitate:

- Rapid breaching of steel-reinforced concrete walls
- Vertical movement inside structures without the use of existing staircases
- Vertical movement on the outside of structures
- Horizontal movement between structures above ground level
- Penetration of pavement and building foundations for movement between surface and sub-surface zones.

Units moving in or between zones need to be able to navigate effectively, and coordinate their activities with units in other zones, as well as with units moving outside the urban environment. The complexity of urban operations will place high demands on the leadership of small units – decentralized execution will require navigation and coordination capabilities be resident at the very small unit level.

The urban environment will also place units and individuals in unfamiliar situations, where senses can easily become disoriented. Movement within urban canyons, subterranean canals, and high-rise superstructures will require specialized training to overcome problems with mobility and navigation.

As important as mobility, US forces will conduct countermobility evolutions to limit or deny the enemy's freedom to maneuver along urban avenues of approach (e.g., streets, subways, passages through buildings). In the attack, when US military units bypass enemy centers of

resistance, they will use countermobility means to contain the enemy within his positions and to seal potential avenues of approach which might facilitate enemy counterattacks. In the defense, countermobility systems and procedures will form an integral part of the overall plan, limiting the enemy's maneuver options and channeling him into killing zones.

US forces must also examine mobility in urban terrain as it impacts evolutions at different levels of war. For example, at the operational level, a commander will be concerned with the capability to exploit a major urban transportation network. On the other hand, at the tactical level, squad leaders will focus on procedures for movement through a small portion of the same major network.

MAJOR UNCERTAINTIES

Although the ability to effectively maneuver in the urban environment is a promising area for innovation, there are three major uncertainties regarding further work in this area. The first uncertainty involves whether or not technology can support the needs of tomorrow's warfighters. For example, the tools needed to effectively maneuver within structures or in subterranean poses a noteworthy technological challenge. The second uncertainty concerns the motivation for commercial development of the types of tools the warfighters need. Finally, the third uncertainty concerns the affordability of systems designed to operate in the urban environment. The types of enablers needed to effectively maneuver may prove to be cost prohibitive.

The affect of these uncertainties can be minimized. Challenges in technology need to be met head on. Systems used by US forces in the urban environment will likely have other applications for civilian law enforcement agencies. Navigation and targeting devices will likely have similar applications for firefighters. The US military should join forces with civilian agencies to encourage industry toward urban innovation. Funding urban initiatives is a second hurdle that needs to be overcome. Military personnel should emphasize that maneuver enablers used for urban terrain will likely be applicable across the spectrum of conflict. Therefore, procurement of these items will facilitate military operations across the board.

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority		Critical Operational Capabilities: Urban Warfare: Fires (lethal and non-lethal)	
Description & Rationale <ul style="list-style-type: none"> Ability to Project Combat Power/Achieve a Desired Effect in Urban Environment <ul style="list-style-type: none"> Deny Areas Shoot, Move, Breath, See, and Navigate in Underground Structures. Maximize Personal Protection Creating Access to Buildings/Enclosed Areas Where No Entry Ability to Automatically Locate Origin of Hostile Fires in Urban Crowd/Population Control Methods to Separate Noncombatants, Influence Combatants in a Crowd. Targeting That Minimizes Collateral Damage to combatants. Ability to Target and Shoot 'Around Corners', up and into Direct Fires 3 Dimensionally. 		Force Characteristics Implications <ul style="list-style-type: none"> Forces Capable of Seeing into the Urban Environment, and Operating With Speed and Accuracy. Forces Capable of Operating Across the Spectrum of Conflict With a Range of Weapons That Vary in Lethality. Forces Will Require Additional Training to Determine Not Only When to Shoot, but What Range of Lethality to Shoot. 	
Enabling Technologies <ul style="list-style-type: none"> Electronic and Aerosol Means for Disabling Vehicles. Non-lethal Measures (Foams, Gels, Acoustics, Etc.) To Hinder/Deny Human Access to Large Areas. Man/Vehicle Portable Devices to Seal Windows, Doors, Manhole Covers, Culverts, Etc. Pneumatic Ram to Open Hardened Rooms/Shelters. Lightweight Individual Protective Clothing Offering 360° Protection Including IFF Lightweight All-Weather Lightweight Targeting Devices With Ability to "See Through" Structures. Sniper Detection and Location System Range Specific Shoulder-Fired Munitions 		Major Uncertainties <ul style="list-style-type: none"> Enabling Technologies Affordability/Funding 	

DESCRIPTION AND RATIONALE

Measured firepower is needed to enable US forces to deny the enemy the protection from the urban environment. US forces need the flexibility to attack targets located within buildings or rubble, and to conduct engagements from surface to sub-surface, and vice-versa. Measured firepower should provide reasonable certainty of achieving the desired effect on the enemy, but with reduced risk of injury to noncombatants. In some situations, for example, US forces might be required to "implode" large buildings defended by the enemy without seriously damaging surrounding structures. In other situations, forces might employ nonlethal weapons to clear structures shared by enemy forces and noncombatants.

The nature of urban terrain will present challenges in employing forces. Limited visibility will affect targeting, fire support coordination, and battle damage assessment. Tall structures will become intervening crests for surface-delivered fires. The cover afforded by the terrain will affect penetration characteristics and fuze functions, reducing weapons effects below the threshold for successful engagement. The fire support system must adapt to these conditions by providing for target location and designation in three-dimensional terms, extremely precise ordnance delivery (e.g., to a specific room in a building), munitions with variable penetration and explosive characteristics, and the coordination of lethal and nonlethal fires against different targets near one another. US forces need to fully understand the expected effects of ammunition when used against different combinations of building materials, the capability to call for and adjust supporting arms in an urban environment need to be resident at the very-small-unit level,

perhaps the squad, and US forces at every level must understand the integration of fire and maneuver in urban terrain.

US forces need the ability to project combat power and achieve a desired effect in the urban environment. The challenges of urban warfare require US forces to be outfitted with tools suited for the urban environment. The multi-tiered nature of urban areas will require forces to be able to shoot, move, breathe, see, and navigate in underground structures. They will need to be able to target and shoot 'around corners,' up into windows, and direct fires three dimensionally. Forces will need to have the ability to automatically detect the origin of hostile fires in urban canyons and, when necessary, create access to buildings where no entry exists. The intermingling of combatants and noncombatants will make identification of belligerents difficult at best. Personal protection devices, crowd/population control methods to separate noncombatants and influence combatants in a crowd, and targeting and munitions that minimize collateral damage to infrastructure and noncombatants will be a necessity.

ENABLING TECHNOLOGIES

Technologies must emphasize the development of both lethal and nonlethal means to deal with the complexities of firepower in the urban environment. Required technologies in the area of nonlethal weapons include:

- ***Electronic and aerosol means for disabling vehicles.*** The ability to disable vehicles without causing damage to surrounding infrastructure will significantly reduce collateral damage and civilian casualties.
- ***Methods to hinder or deny human access to large areas.*** Promising technologies include foams, gels, and acoustic devices.
- ***Man/vehicle portable devices to seal windows, doors, manhole covers, culverts, and other portals for entering or exiting buildings.*** Technologies in this area will allow forces to secure buildings and subterranean accesses without physically entering the structure or causing large amounts of collateral damage. This technology also enhances force protection.

For lethal fires, innovative technologies can provide forces with:

- ***'Shoot around the corner' capability.*** Range-specific, shoulder-fired munitions will allow troops to fire a round that explodes after travelling a user-determined distance. For example, after determining the approximate distance to the end of a building, a soldier would 'program' the round to travel that distance plus a short distance further. After firing, the munition would travel the required distance and explode, literally allowing the shooter to project lethal fires 'around the corner.'
- ***Sensing, penetrating munitions.*** This idea concerns munitions that can be directed to penetrate a specific distance through an object or to count the number of obstructions through which it travels before exploding. This technology would be useful when targeting inside a structure (e.g., the tenth floor of a thirteen-story building) while minimizing collateral damage.

- ***Sniper detection and locating systems.*** Either a man or vehicle portable weapon capable of detecting azimuth and elevation from which fires originate, and automatically returning fire in the same direction.

To enhance the ability to deliver fires, friendly forces will require:

- ***3-dimensional mapping capability.*** Troops operating in the urban environment will need to know their precise location and the location of their target in three dimensions.
- ***Devices that are able to “see through” structures.*** Urban terrain compounds the problem of locating enemy forces/belligerents in the urban environment. Forces operating in the urban environment will need to have the tools to “see” through and into buildings in order to locate and target belligerents.

FORCE CHARACTERISTICS IMPLICATIONS

The urban terrain, high potential for excess collateral damage, and intermingling of belligerents with noncombatants poses unique challenges for the forces of tomorrow. Providing 21st century warfighters with the tools they require to effectively conduct their job will greatly facilitate their ability to fight and survive in urban areas – while at the same time safeguarding people and property – will have significant implications on the character of the force. Technological enablers, such as those previously discussed, will impact the way US forces are employed and trained.

- ***Forces will be capable of seeing into the urban environment and operating with speed and accuracy.*** Unprecedented technology will allow 21st century fighting forces to “see” into building and navigate in three dimensions. Uncertainty will be replaced by confidence; US forces will thrive in the confines of the urban jungle.
- ***Forces will be capable of operating across the spectrum of conflict with a range of weapons that vary in lethality.*** US forces will find themselves in situations where they are simultaneously conducting humanitarian, peacekeeping, and combat operations. Technological innovations in firepower will allow forces to scale the degree of firepower employed depending on the particular situation.
- Forces will require additional training to determine not only when to shoot, but what range of lethality to shoot. Effective employment of the new technologies will require additional training on the use and effects of all weapons used in the urban environment to minimize both collateral damage and lethal involvement of nonbelligerents.

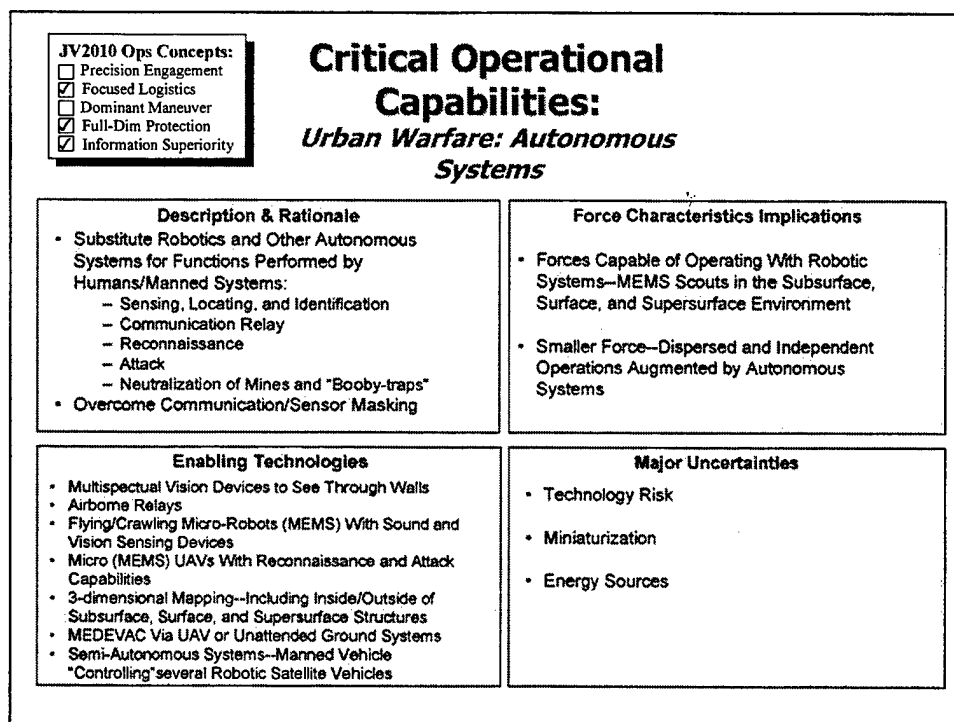
MAJOR UNCERTAINTIES

Although the ability to effectively employ fires in the urban environment is a promising area for innovation, there are two major uncertainties regarding further work in this area. The first uncertainty involves whether or not technology can support the needs of tomorrow’s warfighters. For example, the ability to detect and identify targets within structures or in subterranean areas

with the necessary resolution to target in three dimensions poses a noteworthy technological challenge. The second uncertainty concerns the affordability of systems designed to operate in the urban environment. The types of enablers needed to deliver scalable fires may prove to be cost prohibitive.

The affect of these uncertainties can be minimized. Challenges in technology must be met head on. Weapon systems used by US forces in the urban environment will likely have other applications for civilian law enforcement agencies. Navigation and targeting devices will likely have similar applications for firefighters. The US military should join forces with civilian agencies to encourage industry toward urban innovation. Funding urban initiatives is a second hurdle that needs to be overcome. Military personnel should emphasize that firepower enablers used for urban terrain will likely be applicable across the spectrum of conflict. Therefore, procurement of these items will facilitate military operations across the board.

URBAN AUTONOMOUS SYSTEMS



DESCRIPTION AND RATIONALE

In future operations in urban terrain, forces will leverage the peculiarities of the urban environment to develop and maintain tempo, thereby creating a cascading, deteriorating effect upon the enemy. This will require new ways of thinking about operations in cities, as well as the exploration of new technologies to facilitate rapid and decisive operations in complex urban conditions. US forces will need the technical capability and the operational acumen to identify the enemy's positions of strength and critical vulnerabilities. Instead of grinding their way from

house to house, US forces will deftly maneuver through built-up areas, using new and unorthodox mobility techniques to avoid surfaces and exploit gaps. They will bypass and isolate the enemy's centers of resistance, striking decisive blows against enemy positions.

FORCE CHARACTERISTICS IMPLICATIONS

By utilizing a family of autonomous systems in the urban environment, a small and independent force can increase its overall awareness and understanding while simultaneously increasing its combat power. Small forces afforded the force multipliers that autonomous scouts, reconnaissance units, sensors, fire-support systems, and attack systems provide can monitor and control the multi-dimensional environment that will exist in the future urban sprawls. With the situational awareness and combat force multiplication that autonomous or semi-autonomous systems provide, forces will be able to adjust the size of their units based on the mission. Moreover, these agile forces will be able to control the multi-dimensional subsurface, surface, and supersurface environment of urban warfare and achieve the desired mission results.

ENABLING TECHNOLOGIES

- Multispectral vision devices that can "see" through walls.
- Airborne relays to assist in integrating communications, intelligence feeds, and position data, along with databases.
- Tactical UAVs or crawling robots such as the Dragon Drone UAV, Dragon Warrior VTOL UAV, or the Hummingbird UAV for reconnaissance, sensing, airborne relay, or attack missions or small "fist-sized" crawling robots for use in enclosed areas such as sewers or inside of buildings.
- Flying or crawling micro-robots (MEMS) with sound and vision sensing devices that can penetrate buildings to detect the location of combatants or noncombatants.⁸
- Three dimensional mapping including inside/outside of subsurface, surface, and supersurface structures.
- Medical evacuation (MEDEVAC) via UAV or unattended ground systems.
- Semi- autonomous systems – manned vehicles controlling several robotic satellite vehicles.
- Autonomous indirect fire systems such as the "Missiles/Smart Rounds in a Box" concept contained in this report or the autonomous mortar system Dragon Fire.
- Dragon Fire Autonomous Mortar System is an extremely quick response highly accurate organic fires weapon. Dragon Fire can address targets in a 360 degree span

⁸ For more information on MEMS robots and MEMS technologies in the urban warfare environment see the White Papers in this report; "MEMS Robot Technologies" by Dr Dennis Polla of the University of Minnesota Microtechnology Laboratory and "The Fly on the Wall: A Concept for Making the Enemy's Area of Operations 'Transparent'" by Dr Eugene Gritton of RAND.

with accurate 120mm indirect fires to ranges of fourteen kilometers. Its primary round is the French designed 120mm mortar, the most powerful of all 120 rounds with 4.3kg of explosive in the HE version, and a full family of munitions in production including smart top-attack anti-armor rounds. Capable of being deployed without a crew, its V-22 compatible design (internal load) and potential for emplacement and employment in locations unsuitable to conventional fires systems offers great tactical flexibility to forces in the urban environment. The Dragon Fire can adjust its configuration to fire virtually any 120mm mortar round now in production, regardless of country of origin.

MAJOR UNCERTAINTIES

The major uncertainties associated with autonomous systems include technological feasibility, specifically in the areas of micro-miniaturization and small power sources.

RECOMMENDATIONS FOR URBAN WARFARE

Continue to conduct limited operational experiments, advanced warfighting experiments, and advance concept technology demonstrations focused on refining concepts, techniques, procedures, and technologies for warfare in the urban environment. Funding for experimentation and research and development for urban warfare associated concepts should continue. Moreover, funding should continue until viable tactics, techniques, procedures, and equipment items have been developed that will ensure the success of US forces operating in the challenging urban battlefield of the 21st century. The lead should be US Marine Corps and US Army. US Air Force and US Navy will participate in supporting roles – particularly close air support, naval surface fire support, and sustainment in the urban warfare arena. Annual cost of experimentation and research in all areas of urban warfare is estimated to be in excess of \$50 million per year. Actual cost data could not be obtained for this report; however, estimated costs for experimentation can be obtained from the Marine Corps Warfighting Laboratory and the US Army Military Operations in Urban Terrain MOUT ACTD. Actual cost for implementing a robust urban warfare capability within the American armed forces would be based on results of experimentation, mission-area analyses, and the surrogate technologies available after the experimentation is complete.

Enabling Technologies MEMS-Based Micro-Robots

- **Multi-functional MEMS Sensor Systems**
 - Deployable microelectronic sensors with vision, sound detection, and chemical analysis capabilities
 - Telemetry with GPS capability
 - Re-configurable network (swarm) under remote control
- **Multi-functional MEMS Actuator Systems**
 - Deployable actuators capable of moving sensor and signal processing payloads in remote locations
 - Air, water, and soil sampling with real-time analysis
 - Active tagging of personnel

DESCRIPTION AND RATIONALE

Microelectromechanical systems (MEMS) represents an emerging technology which incorporates sensors, actuators, and signal and information processing on a common semiconductor substrate.⁹ Because the manufacturing methods for making MEMS are derived from the same processes used in making memory chips and other integrated circuits, the potential exists for having both small and inexpensive smart systems.

The micro-robot concept incorporates variety of *microsensors* on a small deployable platform. The platform size is generally smaller than a cubic centimeter and may even be smaller than 10^{-3} mm^3 . These sensors might include any combination of the following: acoustic sensors to detect the presence of personnel or movement of equipment, multi-spectral radiation sensors such as medium infrared to detect personnel, and chemical sensors to detect signatures associated with the presence or manufacture of weapons of mass destruction.

The micro-robot concept also incorporates *microactuators* to effect controlled movements of the robotic platform. This might include the capability for some robots to navigate on the ground, others to move through the air, and others to move through water. Deployable micro-robots

⁹ W. S. Trimmer, Micromechanics and MEMS: Classic and Seminal Papers to 1990, IEEE Press, New York, N.Y., 1997.
S.M., Sze, Semiconductor Sensors, John Wiley and Sons, Somerset, N.J., 1994.
R.S. Muller, R.T. Rowe, S.D. Senturia, R.L. Smith, and R.M. White, eds., Microsensors IEEE Press, New York, N.Y., 1990.
G. Kovacs, Micromachined Transducers Sourcebook, McGraw-Hill, New York, N.Y., 1998.

might collectively move in a manner similar to insects such as bees sensing information over widely dispersed terrain or being locally directed to a specific room in a building.

Specialized microactuators on the robotic platform can potentially open microfluidic sampling chambers to collect air/water specimens or perform a real-time chemical or biochemical analysis. This capability may be important in identifying the likelihood of the presence of chemical or biological warfare agents in the environment.

More specialized micro-robots might emulate the size and behavior of mosquitoes seeking out the presence of humans and inserting a tiny proboscis (less than 50 μm in diameter) through the skin. A small micropump might deliver a small amount of chemical (1 μL or less) to incapacitate personnel in a localized area.

Because the MEMS technologies used in the manufacture of the robot platforms is the same as those used in making integrated circuits, specialized microprocessors can be integrated on-chip with the robots. Additionally, the semiconductor common platform can support telemetry and GPS capabilities. The specific further technology development challenges to achieving this are more fully discussed in the later sections of this paper.

The potential application of MEMS to urban warfare is tremendous. Special dedicated functionalities and configurations such as that shown in the following figure can be assigned to each insect-like robot (A = acoustic sensing; I = imaging; T = telecommunications with the swarm and battlefield commander; K = incapacitation, both lethal and non-lethal). Each species can operate autonomously or be commanded to carry out a specific highly-coordinated task. A large number of multi-sensing tasks as well as directed movements and actuation can be potentially performed autonomously and in unfriendly environments.

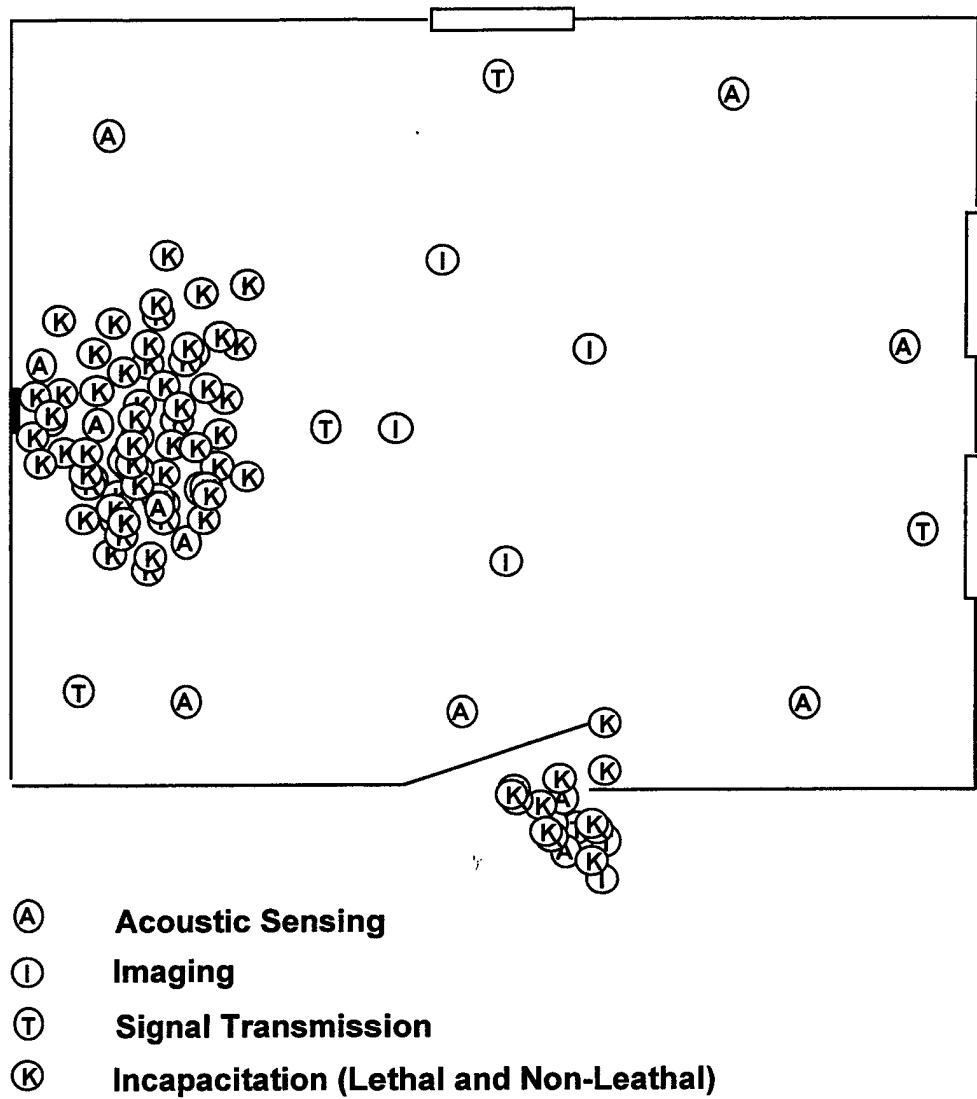


Fig. 1. Schematic concept of controlled MEMS-based flying robots deploying in a room. Each species performs only one function has its own commandable and networked functional capability. Autonomous movement of some robots have a directed algorithm to navigate through door openings and stairwells.

FORCE CHARACTERISTICS IMPLICATIONS

MEMS-based micro-robots would allow new information to be available to defense personnel and central command locations. MEMS micro-robotics moving in advance of troops would provide important information concerning targets, enemy personnel, and environmental hazards. The ability to deploy micro-robots in building and underground facilities would provide information that is currently unobtainable.

ENABLING TECHNOLOGIES

Several key MEMS capabilities have already been demonstrated in commercial applications. DARPA has also been funding MEMS technologies for defense applications since 1992¹⁰. The technologies developed to-date can be adopted to realize micro-robot systems with somewhat limited capabilities. By the Year 2010 many of the micro-robotic urban warfare concepts should be feasible. Some key enabling technologies are listed below.

- *MEMS-based GPS.* Analog Devices, Inc. (Cambridge, Massachusetts) has developed a family of MEMS-based microaccelerometers primarily addressing the needs of the automotive industry¹¹. The electrostatic inertial comb-drive sensor technology¹² developed can also be applied to multi-axis accelerometers and GPS. In addition to performing GPS tasks for the micro-robot, this same technology has other potential defense applications such as personnel monitoring and asset tracking, missile targeting and controlled activation, tagging, etc. Other US MEMS accelerometer suppliers exist including Motorola (Phoenix, Arizona), Nova Sensor (Fremont, California), IC Sensors (Fremont, California), and Honeywell (Plymouth, Minnesota).
- *Bioanalytic microchips.* Considerable interest currently exists in the application of MEMS technology to biochemical analysis¹³. A diverse range of commercial applications include human health care, drug discovery, and animal and plant genetics. MEMS components such as microfabricated chemical reaction reservoirs, microfluidic capillaries, pumps, valves, and molecular recognition biosensors are currently being developed. This technology integrates microfluidics, biochemistry, and electronics. Several commercial applications are emerging such as the Affymetrix GeneChipTM (Santa Clara, California)¹⁴. For micro-robotic defense applications the technologies described above can be tailored to develop molecular recognition biosensors¹⁵ and biosensor arrays for the detection of specific biochemicals.
- *Acoustic emission microsensors.* Structural health monitoring devices are currently under development by ONR¹⁶. These devices sense small acoustic energy bursts due to material fatigue and cracking in critical aircraft components. Detection and signal processing algorithms have been developed to alert the pilot of these aircraft to incipient catastrophic failure. The key enabling technology is a MEMS-based 200 μm diameter high-frequency acoustic emission sensor with on-chip signal processing and telemetry capability. For micro-robotic applications this technology can be tailored to identify acoustic patterns associated with the movement of human beings and

¹⁰ DARPA Report, *Microelectromechanical Systems (MEMS)*, 1995.

¹¹ S. J. Sherman, W. K. Tsang, T. A. Core, R. S. Payne, D. E. Quinn, K. H.-L. Chau, and J. A. Farash, "A Low Cost Monolithic Accelerometer; Product/Technology Update," *Proceedings of IEEE Int. Electron Devices Meeting*, San Francisco, CA, 1992, pp. 501-504.

¹² T. Juneau, A. P. Pisano, and J. H. Smith, "Dual Axis Operation of a Micromachined Rate Gyroscope," *Proceeding of the 1997 Int. Conference on Solid-State Sensors and Actuators*, Chicago, IL, 1997, pp. 883-886.

¹³ E. Kress-Rogers, ed., *Handbook of Biosensors and Electronic Noses*, CRC Press, Boca Raton, FL, 1997.

¹⁴ *Annual Report*, Affymetrix, Inc., 1998.

¹⁵ R. C. McGlennen, S. Zurn, D. Charych, and D. L. Polla, "Molecular Recognition Cantilever," *Proc. 9th International Symposium on Integrated Ferroelectrics*, Santa Fe, NM, Mar. 1997.

¹⁶ D. L. Polla and L. F. Francis, "Ferroelectric Thin Films in MEMS Applications," cover article for *Materials Research Society Bulletin*, V. 21, No. 7, July 1996, pp. 59-65.

equipment. Telemetry from several acoustic sensors to a local monitoring station can provide an acoustic mapping of the likely personnel and equipment in a specific area.

- *MEMS-Based Microphones.* Several MEMS-based microphones¹⁷ hearing aids are currently under development. The key features of these devices are small size and high sensitivity. Micro-robots capable of deploying these devices can provide a listening capability in buildings for both identification of presence as well as eavesdropping.
- *Uncooled MEMS Imaging Arrays.* MEMS-based infrared imaging arrays^{18,19} are under active development through the Army Night Vision Laboratory. Solid-state micromachining advances have allowed for the formation of low thermal mass structures with excellent thermal isolation. Both pyroelectric and resistive bolometers have shown the ability to perform uncooled infrared imaging.
- *MEMS Micromotors.* MEMS-based micromotors have shown considerable development since their first disclosure in 1988.^{20,21} Although the initial rotating electrostatic micromotors developed by AT&T Bell Laboratories and University of California at Berkeley which stimulated a large scientific interest in MEMS have not been successfully applied in practical applications, both piezoelectric²² and electromagnetic²³ micromotors now appear to have commercial promise. Specifically, MEMS-based piezoelectric micromotors have been used in eye surgery²⁴ and electromagnetic micromotors have been demonstrated the ability to produce self-levitation (> 10 cm above ground) similar to that of a miniature helicopter. Miniature electromagnetic micromotors of 1.9 mm diameter and 4 mm length have been shown to produce self-levitation.²⁵ Future technology developments in both piezoelectric and electromagnetic micromotors should provide important capabilities for directed ground, air, and water movements.
- *MEMS-Based Telemetry.* Several commercial applications of MEMS telemetry²⁶ are under development for both medical patient care monitoring and industrial process control. Tiny microchips with specific telemetry resolutions, encoding schemes, and

¹⁷ P. R. Scheeper, A. G. H. van der Donk, W. Olthuis, and P. Bergveld, "A Review of Silicon Microphones," *Sensors and Actuators*, Vol. A44, No. 1, 1994, pp. 1-11.

¹⁸ L. Pham and D. L. Polla, "Surface-Micromachined Pyroelectric Infrared Imaging Array with Vertically Integrated Signal Processing Circuitry," *IEEE Trans. On Ultrasonics, Ferroelectrics, and Frequency Control*, UFFC-41, 552, July 1994.

¹⁹ D. D. Skatrud and P. W. Kruse, eds. Chapter in "Uncooled Infrared Imaging Arrays and Systems," *Semiconductors and Semimetals*, Academic Press, 1997.

²⁰ Y.-C. Tai and R. S. Muller, "IC-Processed Electrostatic Synchronous Micromotors," *Sensors and Actuators*, Vol. 20, Nos. 1-2, 1989, pp. 49-55.

²¹ W. S. N. Trimmer and K. J. Gabriel, "Design Considerations for a Practical Electrostatic Micro-Motor," *Sensors and Actuators*, Vol. 11, No. 2, 1987, pp. 189-206.

²² D. L. Polla and L. F. Francis, "Ferroelectric Thin Film Materials for MEMS," *Ann. Materials Review*, 1998.

²³ U. Berg, M. Begemann, B. Hagemann, and K.-P. Kamper, "Series Production and Testing of a Micro Motor," *Proceedings of Actuators '98*, Bremen, Germany, June 1998, paper 6.4.

²⁴ D. Polla, "Piezoelectric MEMS," *Proc. 10th International Symposium on Integrated Ferroelectrics*, Monterey, CA, Mar. 1998.

²⁵ C. Thurigen, U. Beckford, R. Bessey, and F. Michel, "Design Rules and Manufacturing of Micro Gear Systems," *Proceedings of Actuators '98*, Bremen, Germany, June 1998, paper P103.

²⁶ W. Winer, et. al., "Integrated Diagnostics," Annual Report to the Office of Naval Research, Contract N00014-95-1-0539, Peter Schmidt, technical monitor, June 1998.

transmission ranges are now feasible. This generic communications capability can be integrated with the micro-robotic platforms envisioned in this paper.

- *Thin Film Batteries and Energy Harvesting Devices.* Research on MEMS energy sources is just beginning.²⁷ Approaches under development include the use of thin film batteries deposited on the backside of silicon microchips and energy harvesting schemes. Energy harvesting methods include scavenging thermal, mechanical, chemical, and radiant energies from the environment. Energy supply possibly realized through a combination of thin film batteries and energy harvesting will be important in determining the ultimate size and functional performance of MEMS micro-robots.

MAJOR UNCERTAINTIES

The major uncertainties for all of the functional forms of MEMS-based micro-robots will be their size and intended performance characteristics. Specifically, it is unknown at this time what the ultimate payloads for deployable robots will be and their associated power requirements. Furthermore, no defense study has been carried out to determine practical defense or warfighting requirements of such robots. These requirements will, of course, determine engineering specifications on the robot design. Given the relative newness of this field, trade-offs in actuation mechanisms, energy requirements, and size have not been performed for defense applications.

For the enabling technologies listed above, the following are key technology challenges which have largely been met but will need to be more fully developed to enable a broad, versatile, range of applications.

MEMS-based GPS. The commercial sector will drive the development of MEMS-based GPS primarily through automotive navigation applications. Precision resolution defense requirements for insect-like robots moving through a building will likely place one or two orders of magnitude additional resolution demand on such GPS systems.

Bioanalytic microchips. Detection of biological and chemical warfare agents requires further development of detection methodologies and strategies, chemical processing protocols, and information extraction methods. Currently bioanalytic MEMS make use of a microchip platform for specimen processing and a separate analytic instrument for assaying and detection. A shared goal of the many researchers working on commercial bioanalytic MEMS is to integrate the microchip platform and analytic instrumentation onto a common carrier chip. For many commercial applications, deployability, miniaturization below the size of personal computer, and portability are not significant driving forces.

Specific microchip-based biochemical assays still need to be developed for the large number of potential chemical and biochemical agents known at this time. The translation of these detection assaying methods to miniature systems still needs to be developed. Issues of biochemical selectivity, specificity, and sensitivity will be major uncertainties with this technology.

- *Acoustic emission microsensors and MEMS-Based Microphones.* Detection and signal processing algorithms of human movements (walking, speech, heartbeats)

²⁷ J. B. Bates, G. R. Gruzalski, N. J. Dudney, C. F. Luck, X.-H. Yu, and S. D. Jones, "Rechargeable Thin-Film Lithium Microbatteries," *Solid State Technology*, Vol. 36, No. 7, 1993, pp. 59-64.

needs to be developed while rejecting ordinary ambient signals such as those associated with HVAC systems or small animals. Acoustic sensitivities for the MEMS devices at the important frequency ranges needs to be established.

- *Uncooled MEMS Imaging Arrays.* Uncooled MEMS-based infrared detector arrays are just beginning to show promise for commercial night vision applications such as driving and personnel monitoring. While these uncooled pyroelectric and other bolometer sensitivities are several orders of magnitude lower than liquid nitrogen-cooled HgCdTe infrared detectors, sensitivities, operating ranges, and operation in environments with changing temperatures still needs to be determined for micro-robot applications.
- *MEMS Micromotors.* Both piezoelectric and electromagnetic micromotors have demonstrated the ability to generate forces greater than 10^{-3} N and in some cases as high as 10 N. Force requirements will directly determine both motor size and power requirements. This will ultimately limit the deployable payload of the micro-robot platform.
- *MEMS-Based Telemetry.* While telemetry microchips have previously been demonstrated, two important concerns are operable transmission distance and power consumption. This in turn determines the size of the broadcast/receive antenna and the information transfer characteristics.
- *Thin Film Batteries and Energy Harvesting Devices.* Thin film batteries have previously been demonstrated but not yet demonstrated in a real world MEMS application. The power delivery and useful operating lifetime are directly determined by the mass of the battery material.

THE FLY ON THE WALL: A CONCEPT FOR MAKING THE ENEMY'S AREA OF OPERATIONS "TRANSPARENT"

JV2010 Ops Concepts: <input checked="" type="checkbox"/> Precision Engagement <input checked="" type="checkbox"/> Focused Logistics <input checked="" type="checkbox"/> Dominant Maneuver <input checked="" type="checkbox"/> Full-Dim Protection <input checked="" type="checkbox"/> Information Superiority	Critical Operational Capabilities: <i>The Fly on the Wall: A Concept for Making the Enemy's Area of Operations "Transparent"</i>	
Description & Rationale <ul style="list-style-type: none"> • Miniature fly-sized vehicles (<1.0 cm) • Carrying a variety of sensors • Observes enemy units and operations unobtrusively • Acquires intelligence and targeting information • Can make "closed" areas open 	Force Characteristics Implications <ul style="list-style-type: none"> • Provides improved ISR to operational commanders <ul style="list-style-type: none"> – particularly useful in urban operations • Some particularly difficult denied areas (e.g., underground facilities, inside buildings, etc.) might become observable • Make the enemy's area of operations "transparent" • Stealth/unobtrusiveness catch the enemy unaware 	
Enabling Technologies <ul style="list-style-type: none"> • Micro (10m - 10m) and nano (10m - 10m) fabrication techniques for electro-mechanical devices and systems • Future information technology • Autonomous system technology • "Everything-on-a-chip" approach 	Major Uncertainties <ul style="list-style-type: none"> • Feasible locomotion approach • Stabilization and navigation • Communication/control • System fabrication to achieve low cost • Operational integration 	

DESCRIPTION AND RATIONALE

This concept, first proposed at a RAND 1992 DARPA Workshop²⁸, consists of "miniature fly or bee sized (<1.0cm) vehicles carrying a variety of sensors for unobtrusive surveillance in a variety of military situations." The successful development of such a system would provide intelligence, surveillance and reconnaissance information to operational commanders not attainable with today's systems. If cheap enough, they could be used in large numbers to observe enemy units unobtrusively. They could acquire intelligence and targeting information and transmit it to command centers or firing units through conventional size repeater units or "hives." Their small size provides inherent stealth and the potential for attaching to enemy personnel or equipment unobtrusively to be carried along with enemy units into previously "closed" areas.

FORCE CHARACTERISTICS IMPLICATIONS

This concept would allow the commander to gain a new resource for gathering reconnaissance and surveillance information on enemy operations. It might be particularly useful in urban and denied areas operations. Such small systems could be used to gather intelligence

²⁸ Richard O. Hundley and Eugene C. Gritton, "Future Technology – Driven Revolutions in Military Operations: Results of a Workshop," DB-110-ARPA, RAND, 1994.

inside of enemy held buildings and improve floor-to-floor and room-to-room clearing tasks. Some particularly difficult denied areas (e.g. underground facilities) might be observable through the use of small microrobots particularly if they are carried inside by unaware enemy personnel or by their vehicles or equipment. If they can be mass produced inexpensively, they could be seeded throughout the battlefield making the enemy's area of operations truly "transparent."

ENABLING TECHNOLOGIES

At the DARPA Workshop and in subsequent unpublished work, order-of-magnitude calculations of the power and energy requirements for mobile microrobots an order-of-magnitude larger (i.e. in the 5-10 cm/5 gm class) indicated useful payloads, speeds and ranges (~ 1.0gm, ~ 9m/sec, and 30-40km) in a device with an all-up system weight of ~4.0gms.

The microrobots would use micro-electromechanical systems (MEMs) and nano- fabrication technologies to develop miniature structural, aerodynamic or mechanical locomotion, propulsion and sensor components.

Advanced information technologies will be challenged to provide the data processing requirements for sensors and autonomous operations. Advances in stabilization and control technologies are all required. Thin film battery technology may provide the answer to power requirements. The ideal would be to achieve an integrated chip capable of providing the sensor data processing, stabilization and navigation functions for the microrobot. The sensor package might even include some chemical processing capability for chemical and biological warfare applications.

MAJOR UNCERTAINTIES

The major uncertainty is the technical feasibility of miniaturizing the components by an order of magnitude from those first examined in the RAND/DARPA Workshop in 1992 (i.e. going from a 10.0 cm to a 1.0 cm class vehicle) with similar performance capability. The development hurdles remain basically the same as discussed at that workshop and are reproduced below.

Very Small Systems: Development Hurdles

Level of Difficulty

Negligible	Low	Medium	High	Very High
	Materials	Power		Navigation
		Locomotion		
Fabrication Techniques				Stabilization
	Sensors	Couplings		Control
				Communications
			Test Diagnostics	

The workshop took a cursory look at the development hurdles confronting very small systems. This chart summarizes our initial impression.²⁹ The semi-precise meanings of the level-of-difficulty categories used on the chart are:

- **Negligible:** The capability is well established. Researchers in the field are doing similar things today.
- **Low:** This can be done using current state-of-the-art, but informed choices must be made.
- **Medium:** Researchers in the field believe they know how to do this, but it will not necessarily be easy.
- **High:** This will be hard to do, but researchers in the field have some ideas of how to attack the problem.
- **Very High:** This will be hard to do, and today researchers do not know how to go about it.

The following comments expand on the entries in the chart above:

- **Fabrication Techniques.** At the centimeter to millimeter scale, "conventional" machining techniques (i.e., small watch scale) can be used for early prototypes. Silicon fabrication techniques should be available for production vehicles.
- **Materials.** There are no real problems here. Several choices are available.

²⁹ These should be viewed as the initial judgments of experts in the area, not as the results of a detailed investigation.

- Power. The first systems should probably use thin-film batteries. Other miniaturized approaches are possible, but need more investigation.
- Locomotion. For *flying*, some data are available, but more checks are needed. For *jumping*, the dynamics are less studied, but the gross attributes do not appear unduly hard. For *swimming*, there is much theory available; hydrodynamic tests will require care.
- Couplings. For the coupling of the energy source to the motor, there is some small-scale experience. For the coupling of motor to actuator, there are limited data in a practical sense. For the details of the actuator, design studies are needed for optimization.³⁰
- Sensors. Optical and infrared sensors are the only sensors facing intrinsic problems due to the small scale; the resolution achievable with miniature optical/IR sensors will be substantially limited by diffraction – much more so than for sensors of more normal size. The effects of noise will be important for miniature sensors of all types. At the beginning of a research program, miniature sensor technologies can be developed and tested separately from integrated locomotion systems.
- Test Diagnostics. This area requires a great deal of attention. Semi-quantitative “go-no go” tests will sometimes be useful, but detailed quantitative measurements will usually be required for design optimization. This will require new types of test instrumentation, which should be considered from the beginning of any program.
- Stabilization and Navigation. This will be one of the major challenges of any micro-vehicle design and test program. Typical issues include how small miniature inertial guidance and automatic stabilization subsystems can be made, etc. As an incremental approach, initial steps could start off with tethered vehicles (for flying systems), or with external stabilization (for jumping systems), with a later transition to the more challenging, completely autonomous stabilization and navigation. Consideration could also be given to design possibilities that minimize orientation requirements (e.g., payloads that work regardless of orientation, etc.)
- Control and Communications. There are a number of miniaturization challenges here. The control and communications approach currently used in clandestine “bugs” could serve as a useful point of departure.

RECOMMENDATION

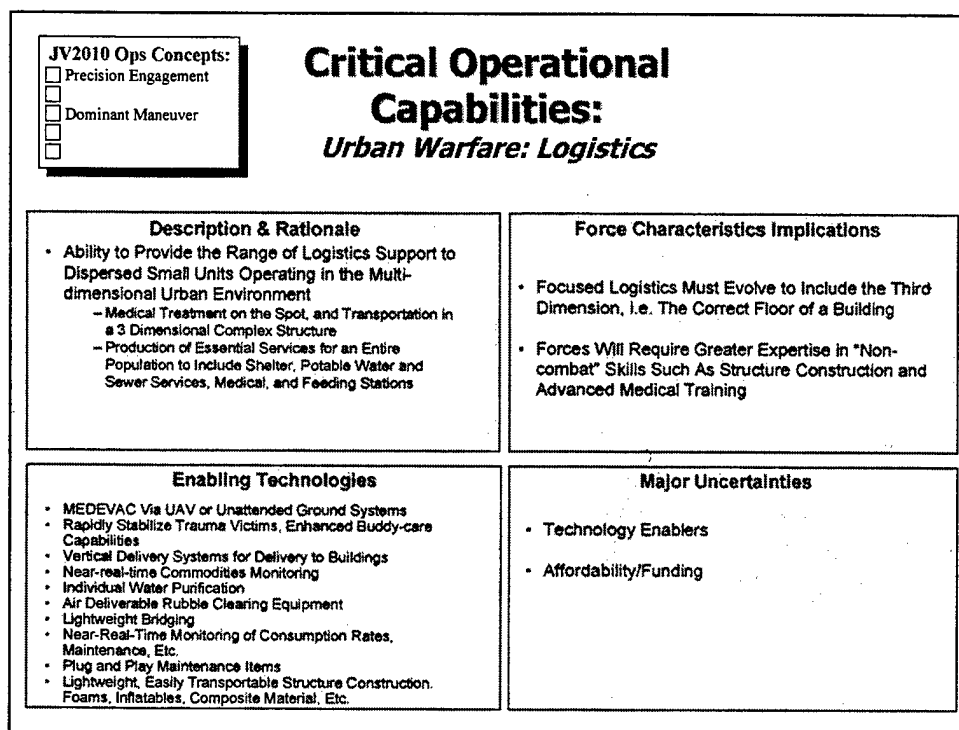
Extend DARPA's micro-UAV program to include two new phases. First, support the completion and closure of the design of a very small UAV (5-10cm, less than 5gm) with limited wind tunnel and tethered flight experiments to identify the key technologies required to build such a system over a three year time period. Second, support at a low level, basic research into the technologies required to determine the feasibility of designing and constructing a true micro UAV (one that is the size and weight of a bee or fly). Integrated with these efforts, should be a

³⁰ As one of many examples of the actuator design issues requiring attention: in a mini-helicopter, should one go to the trouble of having flap joints in the rotor?

significant and complementary program focused on identifying missions and applications in a set of well-posed scenarios, to provide early guidance on sensor and system needs and on meeting the affordability criteria for the two systems described above.

DARPA should take the lead on this program. The first phase of the effort is estimated to cost \$30 million over a 3-year period; phase two costs are estimated at \$5 million per year for 3 years, after which resource requirements should be reinvested.

URBAN LOGISTICS



FORCE CHARACTERISTICS IMPLICATIONS

Urban combat has historically resulted in high casualties, particularly among units attempting to maneuver through streets forming narrow and exposed avenues of approach, against enemy units entrenched in the rugged terrain of the city. US forces will use force protection measures adapted for future MOUT to facilitate maneuver with reduced risk of casualties. Individual and collective protection might serve to lower the incidence of some types of casualties.

Protective measures required for future MOUT would also include special medical capabilities. Individual US forces will be exposed to a wide variety of infectious diseases which breed in the close and heavily populated environment of a city. This exposure might be limited through means such as anti-biotic body-covering ointments or personal air filtration systems which could reduce the probability of inhalation or absorption of disease-carrying organisms. The nature of the terrain will result in a greater number of accidental injuries than are normally

encountered in other operating environments: US forces will fall from heights, they will suffer cuts from glass and other sharp objects, and they will be hit by falling debris. US forces might be wounded while in locations from which it is difficult to evacuate them: a flooded subway or sewer, a major intersection swept by enemy fire, the 30th floor of a 40-story building in which the enemy holds many upper and lower floors. Systems need to be in place to provide for prompt and effective care of the wounded under such challenging circumstances.

Logistics sets the bounds for what is operationally possible. In future MOUT, the logistics system must adapt to the characteristics of the environment to enhance tempo. The two distinguishing features of urban operations – the terrain and the presence of noncombatants – will both impact logistics. Measures which contribute to overcoming the logistics challenges of the urban battlespace can be said to enhance “sustainability.”

At the tactical level of war, combat service support organizations must provide for supply, maintenance, transportation, health services, engineering, and services under the special conditions of MOUT. CSS organizations must be able to locate and reach dispersed elements of supported units in “vertical” urban terrain. Functions which occur routinely under field conditions will take on new dimensions in MOUT: salvage and repair of an armored vehicle in a narrow street, evacuation of wounded US forces from the upper portion of a skyscraper, and resupply of units operating in a storm sewer.

ENABLING TECHNOLOGIES

- Medical evacuation (MEDEVAC) via UAVs or unattended ground systems to ensure rapid evacuation of critical patients from the battlespace with minimal manpower requirements.
- Medical technologies and techniques to rapidly stabilize trauma victims via enhanced buddy care capabilities.
- Vertical delivery systems for delivery to buildings without exposing logistics elements to ambushes and fires.
- Near real time commodities monitoring by new information systems to ensure that logistics managers can provide just in time support to maneuver units.
- Individual water purification to ensure potable water and minimize potential for disease in deteriorating urban context while reducing logistics burdens to forward units.
- Air deliverable rubble clearing equipment
- Lightweight bridging to facilitate crossing of destroyed areas.
- Plug and play maintenance
- Lightweight easily transportable structure construction. Foams, inflatables, composite materials, etc.

MAJOR UNCERTAINTIES

The major uncertainties related to logistics for urban warfare are principally affordability related. Significant funding is required to reduce the burden of sustaining an urban conflict. Additionally, technology enablers in medical systems, energy sources, and unmanned systems must be developed.

*LESSONS FROM THE BATTLE FOR GROZNY*³¹

INITIAL TROUBLES

When the Chechen troubles began, the Russian Army had been operating with little money and bare bones logistical support. It had not conducted a regiment- or division-scale field training exercise in over two years, and its battalions were lucky to conduct field training once a year. Most battalions were manned at 55% or less. Approximately 85% of Russian youth were exempt or deferred from the draft, forcing the army to accept conscripts with criminal records, health problems or mental incapacity. The Russian Army lacked housing for its officers and had trouble adequately feeding and paying its soldiers. It invaded Chechnya with a rag-tag collection of various units, without an adequate support base. When the Chechens stood their ground, the sorry state of the Russian Army became apparent to the world.

Before invading with regular forces, the Russians had trained and supplied the rebel Chechen forces that were hostile to the incumbent Chechen government. A force of 5,000 Chechen rebels and 85 Russian soldiers with 170 Russian tanks attempted to overthrow the Chechen government with a coup de main by capturing Grozny "from the march" as they had in years past captured Prague and Kabul. They failed and lost 67 tanks in city fighting.

A SECOND MISTAKE

Instead of regrouping and waiting to regain surprise, Russian leaders ordered the army into Chechnya with no fully ready divisions. The Russian Army was forced to combine small units and send them to fight. Infantry fighting vehicles went to war with their crews, but with little or no infantry on board. In some cases, officers drove because soldiers were not available. Intelligence on the situation in Grozny was inadequate. Only a few large-scale maps were available, and there were no maps available to tactical commanders. To make matters worse, because the city was not surrounded and cut off, the Chechen government was able to reinforce its forces throughout the battle.

When the Russians first attempted to seize Grozny the last day of 1994, they tried to do it with tanks and personnel carriers but without enough supporting infantry. The available infantry had just been thrown together, and many did not know even the last names of their fellow soldiers. They were told that they were part of a police action. Some did not have weapons. Many were sleeping in the carriers even as the columns rolled into Grozny. Tank crews had no

³¹ By Lester W. Grau, Foreign Military Studies Office, National Defense University, Institute for National Strategic Studies

machine gun ammunition. Lax preparation for this assault reflected the attitude of the defense minister, General Pavel Grachev, who had boasted earlier that month that he could seize Grozny in two hours with one parachute regiment. So the Russians drove into Grozny expecting to capture the city center and seat of government with only token resistance.

But, tanks and personnel carriers, in the city without dismounted infantry support, were easy targets to antitank gunners firing from the flanks or from above. The initial Russian armored columns were swallowed up in the city streets and destroyed by Chechen gunners.

After losing 105 of 120 tanks and personnel carriers the Russians fell back to consolidate for the long, building-by-building battle.

PLANNING FOR URBAN COMBAT

Russian intelligence missed the rapid construction of robust Chechen defenses in Grozny. The Russian columns, moving on parallel but nonsupporting axes, were cut off and destroyed by Chechen forces. Russian planners concluded that high-tempo mounted thrusts to seize defended cities are both ineffective and unjustified in terms of the attrition of personnel and equipment. They concluded that contemporary urban combat requires the following steps.

1. All approaches to the city must be sealed off while detailed reconnaissance proceeds.
2. Key installations and buildings on the outskirts of the city must be taken once artillery has suppressed defenders and assault positions have been occupied.
3. The city's residential, industrial and central sections must be taken successively.
4. Trapped enemy units must be eliminated, mines cleared, weapons collected and military control and curfew established.

These steps obviously suggest to planners that the first objective should be major industrial plants on the outskirts of cities covering axes into the city. Because such plants, with their concrete and stone walls and underground rooms and passages, are ideal for a lengthy, stubborn defense they must be captured before the city can be attacked. Within the city, attacking forces must anticipate (1) defending tanks and direct-fire artillery in corner buildings or behind breaks in walls, (2) dismounted infantry on any story of buildings, (3) snipers and artillery observers in high-rise buildings, attics, and towers.

Collateral damage, not a major consideration when fighting on foreign soil, becomes a particular worry when fighting in your own cities where your own people live.

INTELLIGENCE PREPARATION OF THE BATTLEFIELD

The Russians did their initial planning on 1:50,000 and 1:100,000 scale maps. They lacked necessary, detailed, larger-scale maps in scale 1:25,000 or 1:12,500. Essential aerial photographs were not available for planning, because Russian satellites had been turned off to save money and few aerial photography missions were flown. Lower-level troop commanders never received vital aerial photographs and large-scale maps.

Despite the unclear intelligence picture, planners failed to take elementary precautions or to forecast how the Chechens might defend the city. As the Russian columns moved to Grozny, they were surprised by snipers, road blocks and other signs of Chechen determination to defend the city.

STORM GROUPS AND DETACHMENTS

Soviet and Russian tactical methodology called for organizing storm groups and storm detachments for city fighting. A storm group is usually a motorized rifle company reinforced with a tank platoon, artillery battery, mortar platoon, AGS-17 automatic grenade launcher platoon, engineer platoon and chemical troops. It advances with a covering and consolidation group (a motorized rifle platoon reinforced with antitank guns, grenade launchers and 82mm mortars) and an obstacle clearing party (combat engineers and mine-sweeping tanks). A storm detachment is usually a motorized rifle battalion reinforced with at least a battalion of artillery, a tank company, an engineer company, an air defense platoon, flamethrower squads and smoke generator personnel. Artillery and air support are available from division assets.

Although storm groups and detachments were formed for urban combat following the New Year's Eve defeat, their formation was often counterproductive because it destroyed what unit integrity existed in platoons, companies and battalions and gave commanders more assets than they could readily deploy and control. It would have been better to use the standard tactical unit, then reinforce it with select weapons systems where needed. For example, a motorized rifle platoon could field storm squads and cover and support squads, and a motorized rifle company could field storm platoons and cover and support platoons. The cover and support units would pin the enemy down by fire while the storm unit attacked. After the attack, the cover and support unit would become a reserve.

EARLY LESSONS

The Russians successfully used direct-fire artillery, RPGs, automatic grenade fire and machine gun fire to pin-down the Chechens while attacking through smoke to seize a building. They tossed grenades through windows and doors before entering.

Engineers effectively blew entry ways into the walls. Two three-man combat teams cleared each room. Once a building was captured, it was prepared for defense. Sewer approaches and enemy approach paths were mined and booby trapped.

Since the battle for a city continues non-stop, the Russians learned that they needed fresh troops and adequate reserves. Soviet doctrine called for a 4:1 advantage in troops for urban combat. Some 60,000 Russians and 12,000 Chechens fought in Grozny, yet the Russian's 5:1 advantage was sometimes not enough, because they had to guard every building that they took.

The Russians also learned that troops need to wear something distinctive (and easily changeable) during the assault to avoid fratricide.

TACTICS, TECHNIQUES AND PROCEDURES

Soviet and Russian tactics specified that tanks would lead the assault in city fighting followed by infantry fighting vehicles and dismounted infantry. Tank columns would move in herringbone formation along city streets. This proved disastrous in Grozny where the high density of antitank weapons threatened armored vehicles, while the depression and elevation limitations of Russian tank guns kept them from engaging targets located in basements or in the upper floors of multi-storied buildings. Antiaircraft guns, such as the ZSU23-4 and 2S6, were effective against these targets. In Grozny, tanks and personnel carriers were formed into armored groups used to seal off captured areas, serve as a counterattack force, provide security for rear installations and support advancing infantry from outside the range of enemy antitank weapons.

The Russians began to take special precautions to protect their tanks and personnel carriers. Besides keeping them behind the infantry, they outfitted some with a cage of wire mesh some 25-30 centimeters away from the hull armor. These cages can defeat the shaped charge of the RPG-7 antitank grenade launcher, as well as protecting the vehicle from a Molotov cocktail or a bundle of antitank grenades. The Chechens fielded antitank hunter killer teams which moved toward the sound of engine noise to kill armored vehicles with volley RPG-7 antitank fire from above, the flanks and behind. The Russians learned to counter these teams by establishing ambushes on all approach routes and then running vehicles into selected areas as bait.

City fighting in Grozny required much larger stocks of hand grenades, smoke grenades, demolition charges and disposable, one-shot antitank grenade launchers (similar to the US light anti-tank weapon) than expected. Each infantry soldier needed a rope with a grappling hook for entering buildings. Light-weight ladders were also very valuable for assaulting infantry. Trained snipers were essential, but were in short supply.

Tank-mounted and dismounted searchlights were useful for night assault in the city. Searchlights (as well as pyrotechnics) temporarily blinded enemy night-vision equipment and dazzled enemy gunners. They produced a psychological attack against the enemy, while helping prevent fratricide in the assault.

ARTILLERY

The Russians learned that conventional artillery fires are best used while approaching the city and while capturing the city outskirts. Then, they would deploy the bulk of their self-propelled artillery in direct-fire support of tanks and infantry. Because massed artillery fires create rubble in the very areas through which a force wants to advance, direct-fire is preferable. Direct fire can be conducted by guns, howitzers, multiple rocket launchers and the 82mm Vasilek automatic mortar. When Russian forces arrived at Grozny, they had few fire support coordinators and forward air controllers. Motorized rifle officers were not skilled in adjusting indirect artillery fire, but could readily aim and adjust direct fire.

AIR POWER

The Russians used a lot of fixed-wing aircraft, but they were of limited tactical value in Grozny. They were used to provide support while artillery was moved into range. Because air

strikes could not be precisely targeted, attack fighter bombers concentrated on large "free-fire" zones. Fixed-wing aircraft proved of more value in attacking targets outside the city.

Helicopter gunships were of much more value. They were used against snipers and weapons in the upper floors. The helicopters flew in behind captured high-rise buildings and would "pop-up" to engage these targets, but had to fly to and from the engagement area using the shelter of captured buildings.

SMOKE AND TEAR-GAS

Smoke and white phosphorus rounds were useful in Grozny. White phosphorus, which burns upon explosion, creates a smoke screen and, because smoke is essential for movement in city fighting, every fourth or fifth Russian artillery or mortar round fired was a smoke or white phosphorus round. The Russians point out a side benefit of white phosphorus is that white phosphorus smoke is toxic and readily penetrates protective mask filters. White phosphorus is not banned by any treaty. Tear gas grenades were also useful in the fighting in Grozny.

PART 2.

Related Studies

CHAPTER 6.

Summary of Prior Defense Science Board Studies

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Summary of Prior Defense Science Board Studies

The work of the 1998 Defense Science Board Summer Study Task Force on *Joint Operations Superiority in the 21st Century* builds on a number of recent DSB studies (both past Summer Studies and other Task Force studies) whose recommendations are highly relevant and support the efforts of this Task Force. These analyses addressed a wide range of threats facing the United States — a spectrum of threats that is individually and collectively difficult and challenging. Topics include information warfare, theater missile defense, logistics, command, control, communications, intelligence surveillance and reconnaissance, advanced simulation, readiness, advanced tactics and technologies, and transnational threats.

The task force reviewed the findings and recommendations of this body of work, with emphasis on highly relevant technologies and operational capabilities that have not yet been fully assimilated by the Department of Defense. Integrating this legacy of DSB studies with the many emerging technologies and capabilities that are relevant to producing a dominant force for the 21st century, the task force identified new capabilities, new ideas, and new emphases which help to underwrite Joint Vision 2010.

This chapter provides an overview of the findings and recommendations of these key studies:

- Report of the Defense Science Board Summer Study on Simulation, Readiness and Prototyping, January 1993
- Report of the Defense Science Board 1994 Summer Study Task Force on Information Architecture for the Battlefield, October 1994
- Report of the Defense Science Board 1995 Summer Study Task Force on Investments for 21st Century Military Superiority, October 1995
- Report of the Defense Science Board/Defense Policy Board Task Force on Theater Missile Defense, January 1996
- Report of the Defense Science Board Task Force on Strategic Mobility, August 1996
- Report of the Defense Science Board 1996 Summer Study Task Force on Tactics and Technologies for 21st Century Military Superiority, Volume I, October 1996
- Report of the Defense Science Board 1996 Summer Study Task Force on Achieving an Innovative Support Structure for 21st Century Military Superiority, November 1996
- Report of the Defense Science Board Task Force on Information Warfare Defense, November 1996
- Report of the Defense Science Board Task Force on Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Integration, February 1997

- Report of the Defense Science Board Task Force on Global Positioning System Phase II, February 1997
- Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Volume I, October 1997
- Report of the Defense Science Board 1998 Summer Study Task Force on DoD Logistics Transformation, Volume I, December 1998.

DEFENSE SCIENCE BOARD TASK FORCE ON SIMULATION, READINESS, AND PROTOTYPING*

The Task Force focused on three key aspects of simulation, readiness and prototyping:

- Assessing the impact of Advanced Distributed Simulation (ADS) on requirements, prototyping, development, training, and readiness
- Defining new ways to exploit the potential for convergence of live, virtual, and constructive simulation methods
- Providing recommendations on science and technology initiatives.

It is the belief of this Task Force that ADS technology can greatly improve training and readiness, will help expedite prototyping, and can transform the acquisition process from within. It is being adopted by the warfighters but it can be exploited in a much larger context. The Task Force has found that the warfighting community has embraced ADS and is extending its utility. The warfighters are applying distributed and multiple simulation methods to improve planning, training, and mission rehearsal. The crux of the matter is that they have developed the confidence to use this technology to prepare for the most serious of circumstances where human lives are at stake. Additionally, ADS technologies can provide the confidence building needed for the transforming in the acquisition process.

The scope of applications for modeling and simulation include requirements definition and analysis, virtual prototyping, program planning, engineering design and manufacturing, test and evaluation, and training and readiness. The approach taken by this Task Force was to develop a hierarchy of enabling technologies and to segregate them into two categories:

- Those which are primarily commercially driven
- Those which are primarily driven by DoD.

FIVE MAJOR RECOMMENDATIONS

- The DDR&E and T&E communities and the Services should:
 - Establish and enforce standards and protocols to facilitate the interoperability and reusability of ADS tools and technologies in training and material development
 - Incorporate standards and protocols into all developments and procurements which contribute to enhancing the ADS environment and its use.

* Report of the Defense Science Board Summer Study on Simulation, Readiness and Prototyping, January 1993, Unclassified. (DTIC #ADA 266125)

- Fully internet training ranges, test facilities, laboratories, service schools, industry, and make them DIS compatible
- (This recommendation has already been put into place)
The CJCS and DDR&E should:
 - Establish a constantly available ADS joint warfare environment and build on existing technology.
- The DDR&E, the T&E community, and the Services should carry out a series of experiments and demonstrations using the ADS environment.
- DDR&E should give priority to investing in the following DoD required ADS tools and technologies:
 - Maturation areas:
 - Simulation scalability (virtual)
 - Fully and semi-automated forces (friendly and enemy)
 - Reusable terrain and environmental data bases
 - Modeling and Simulation construction support tools
 - Verification, Validation, and Accreditation
 - Void Areas
 - Virtual simulation support for the individual combatant
 - Combining some live-constructive-virtual simulation interactions
 - Simulation support tools for logistics, medical, maintenance and other support functions
- The Deputy Secretary of Defense should:
 - Direct procurement of ADS technologies in a modular/evolving process which closely couples users and developers and exempts ADS from the 5000.1 process
 - Select and execute several acquisitions programs which will employ an ADS environment for all steps from concept to fielding to build confidence in modification of 5000.1 to include fast track and step skipping measures

DEFENSE SCIENCE BOARD TASK FORCE ON INFORMATION ARCHITECTURE FOR THE BATTLEFIELD*

This Defense Science Board Summer Study Task Force was charged to make recommendations for implementing an information architecture that would enhance combat operations by providing commanders and forces at all levels with required information displayed for assimilation. The Task Force addressed four aspects of information architecture for the battlefield: the use of information in warfare, the use of information warfare, both offensive and defensive; the business practices of the DoD in acquiring and using battlefield information systems; and the underlying technology required to develop and implement these systems.

FINDINGS

- Make the warfighter an informed customer.
- Warfighters need to change information systems to accomplish different missions.
- US information systems are highly vulnerable to information warfare, as are those of US adversaries.
- Buy commercial products, buy commercial services, "buy into" commercial practices.

RECOMMENDATIONS

Information in Warfare

- The Secretary of Defense create a Battlefield Information Task Force (BITF) to:
 - Bring together warfighters and developers to establish the future vision, system, needs, and evolutionary development plans of the operational information system;
 - Create and utilize "joint battlespace" Advanced Concept Technology Demonstrations (ACTDs) to optimize existing capabilities and demonstrate future growth (e.g. broadcast/request modes);
 - Identify and track C⁴I performance metrics;
- The BITF explore direct broadcast satellite service for Warfighter (increase capacity via broadcast downlink).
- The BITF develop future vision for providing more robust wideband communications capacity to CINCs and echelons of command below Division/Wing/Carrier Battle Group (CVBG), and explore other space-based commercial information services to allow real-time surge.

* *Report of the Defense Science Board 1994 Summer Study Task Force on Information Architecture for the Battlefield*, October 1994, Unclassified. (DTIC # ADA 286745)

- The CJCS provide increased technical billets to give the CINCs better staff support-
 - Strengthen CINC's technical expertise;
 - Establish Information Warfare Officer.
- The DDR&E Defense Modeling and Simulation Office (DMSO) with USACOM, Joint Warfighter Center (JWFC), and Joint Staff Element for Operational Plans and Interoperability (J-7) combine and expand DoD capabilities for exercises, games, simulations, and models in C⁴I to enable operation "from the same seat" for readiness assessment, requirements for acquisition, debugging, verification of interoperability, training, rehearsal, confidence building, mission planning, and BDA.

DEFENSIVE INFORMATION WARFARE

- The Secretary of Defense undertake a broad net assessment of Information Warfare (IW) including the involvement of the BITF as an aid in DoD planning and policy development and as an input to national IW policy review.
- The Secretary of Defense support a focus on protection of critical services by supporting immediate increases in funding for and emphasis on defense IW.
- The Secretary of Defense establish a Red Team to evaluate IW readiness and vulnerabilities.
- The Vice Chair, Joint Chiefs of Staff create a Joint Strategy cell for offensive and defensive IW integrated at a Flag level and reporting to the VCJCS. This strategy cell should be tasked to develop a DoD-wide IW strategy.

BUSINESS PRACTICES

- The Deputy Secretary should ratify role of the Defense Information Systems Agency (DISA) as technical architect for interfaces, standards, and interoperability. The USD(A&T) should augment acquisition reform efforts to assure compatibility with the extremely short development and product lifetimes of commercial software and microelectronics.

DEFENSE SCIENCE BOARD 1995 SUMMER STUDY ON INVESTMENTS FOR 21ST CENTURY MILITARY SUPERIORITY*

The 1995 Defense Science Board (DSB) Summer Study was charged to develop an investment strategy for the Department of Defense to assure military superiority of US forces in the 21st Century. Today's complex national security environment, the severe constraints placed on the Defense budget, and the national security and national military strategies require that US forces remain technologically superior. Maintenance of such superiority requires investments in: the highest leverage technologies, innovative operational concepts, new tactics and doctrine, and efficient management approaches.

The Task Force strongly believes that DoD needs to change its course. There is too little emphasis on addressing the emerging challenges of the 21st Century. The Department is busy focusing on downsizing and maintaining the variety of programs that are the legacy of past decades. The Task Force doesn't believe that such a "business as usual" approach will suffice. From the view of this Task Force, potential US adversaries are undergoing a "Revolution in Military Affairs." DoD must respond to this revolution. The Task Force proposes a three-pronged response:

- A US Revolution in Military Affairs
- A US Revolution in Intelligence Affairs
- A US Revolution in Business Affairs

The Task Force believes that investments must be made to provide both superior forces and an overall force structure that is smaller and more affordable. However, acquisition reform must be accelerated and expanded, and resources must be reallocated for 21st century warfare. Some important affordability trade-offs must be made if the DoD is to evolve such a force structure in time.

The above summary highlights the Task Force view that action must be taken at the highest levels within DoD and the Intelligence Community in order to bring about the Revolutions in Intelligence Affairs, Military Affairs and Business Affairs. The details of action are presented in the discussion that follows.

IMPLEMENT A REVOLUTION IN INTELLIGENCE AFFAIRS

The time is right for a greatly renewed emphasis on HUMINT and related collection disciplines within the Intelligence Community resource allocation process. This Task Force has identified four areas (including aids to Human Intelligence - HUMINT) where investments in new technology can support such an increase in emphasis. The Task Force strongly endorses

* *Report of the Defense Science Board 1995 Summer Study Task Force on Investments for 21st Century Military Superiority*, October 1995, (DTIC #ADC 057361)

investments in aids for HUMINT, innovative SIGINT techniques aimed at recent trends in RF emissions and telecommunications, a proactive posture with regard to information warfare, and more aggressive exploitation of open-source, on-line information. Particular emphasis should be placed on using the Internet as a collection vehicle. In addition, the Task Force recommends review of existing laws to ensure that modern information systems can be used by the Intelligence Community as sources of information on foreign adversaries.

IMPLEMENT A REVOLUTION IN MILITARY AFFAIRS (RMA)

Although there is evidence that precision warfare can facilitate the Revolution in Military Affairs, the Department needs a mechanism to ensure that such capabilities can withstand the countermeasures of an innovative adversary. To this end, the Task Force strongly supports the constitution of an aggressive Red Team to identify and exploit the IRSTA, and precision weaponry that underlie such a capability in terms of susceptibilities and vulnerabilities. Such a Red Team effort should build on the ongoing Air Force Counter-PGM Red Team. This Task Force initiated mini-assessments of the kind envisioned; the DSB review of the Global Positioning System vulnerabilities is one specific example. To adequately cope with the external "RMA," Red Teaming is essential.

Secondly, this Task Force found that an offensive information effort is essential to the defense of critical US information systems. Information warfare provides potential adversaries with the ability to launch an attack on the continental US from anywhere in the world. Defense of critical systems is required, as is some level of protection of the total flow of military information, which can be on any telecommunications link operational in the world. DoD emphasis on information warfare must increase, including both offensive and defensive IW.

Finally, DoD should establish a small group within the Joint Staff with the task of creating an integrated warfare system across the range of warfare types. Several candidate warfare applications recommended by this Task Force for early treatment by this JCS team are listed below.

The Task Force finds countering the three types of weapons of mass destruction (nuclear, chemical and biological) to be one of the most daunting challenges facing the Department. There are potential areas of investment that show promise toward mitigating such threats. The Task Force supports ongoing efforts to counter the nuclear and chemical threats, but sees the need for more investment and innovation in countering the biological warfare threat. In particular, the US biology and biotechnology community leads the world in research and product development. However, DoD does not now have a strong enough link to this community. With the BW threat, this situation has dramatically changed. DoD must now forge strong links with this community. The detailed recommendations presented earlier in this report are focused on strengthening such a linkage.

The Task Force saw strong evidence that the potential adversaries that the US is likely to face in the 21st Century are moving key facilities underground and are locating many military assets within urban areas. Again, the group sees promising investment areas to counter this trend, particularly in the detection and characterization of such potential targets and in the penetration

of deeply buried targets using conventional hypervelocity projectiles. The Task Force sees a fragmentation of DoD's efforts in this area and recommends a stronger management focus in order to exploit promising approaches.

Next, the DoD faces severe challenges in strategic lift and logistics. Today's operational approaches and systems will not likely survive the hostile threat environment of the 21st Century adversary. The US will not likely be permitted the long build up period available during the Gulf War. The US will be challenged from ports of debarkation through delivery of forces and support in the field. DoD should pursue innovative concepts for strategic mobility and logistics support, such as the US Marine Corps Operational Maneuver from the Sea, in order to provide a more robust capability in the future.

Finally, the Task Force made recommendations in the areas of submarines, anti-submarine warfare, mine countermeasures, and military operations in built-up areas.

IMPLEMENT A REVOLUTION IN BUSINESS AFFAIRS (RBA)

In order to provide the resources to pursue the initiatives outlined above, the Task Force strongly endorses a true "Revolution in Business Affairs," as outlined within this report. DoD personnel should be focused on preparing for, and fighting, wars or supporting contingencies. All other support and services should be outsourced to world-class private sector organizations. This will allow the DoD to exploit the many investments of the private sector, while providing greater focus for DoD personnel. This group has identified promising trade-off areas for implementation of such an outsourcing policy. For this to work the Department must change the incentive system. DoD personnel must be rewarded for innovative exploitation of the private sector, rather than for the size of their organization. This culture change must come from the top.

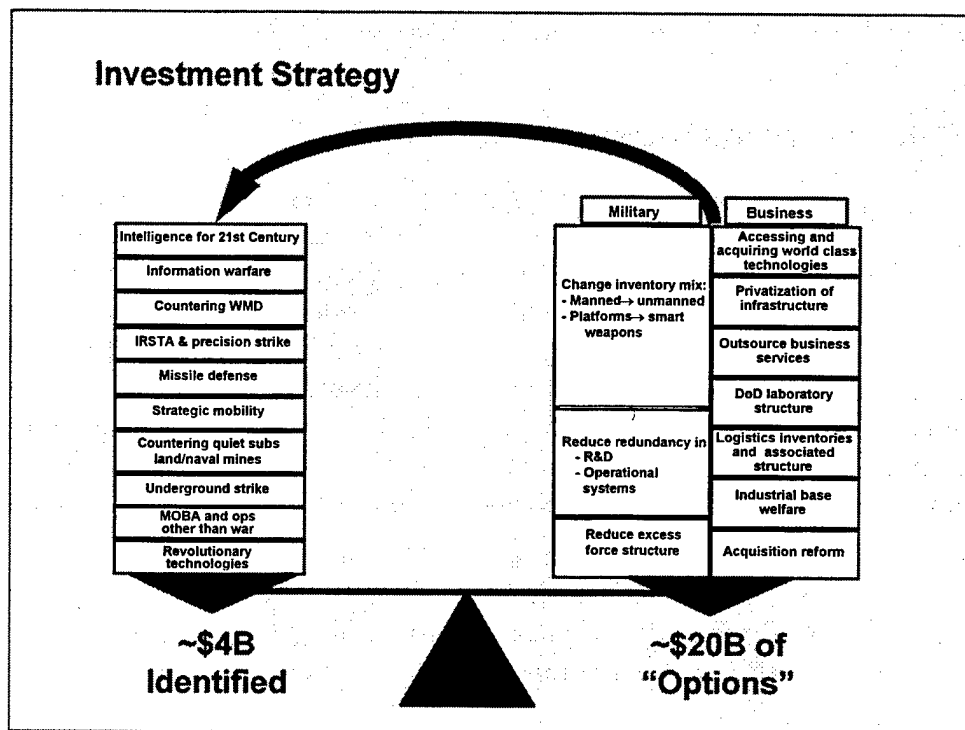
Although DoD has pursued acquisition reform over the last several years, more is needed. Such reform must be expanded to address reform of R&D, system modifications and upgrades, and broad industrial sectors (e.g., jet engines). Further, the Task Force has outlined four new organizational steps to further the Revolution in Business Affairs.

DoD INVESTMENT

DoD RDT&E budgets have declined in real terms over the last seven years, a trend that is currently projected to continue at least through FY 2001. The concurrent downsizing of DoD procurement budgets has seriously eroded the levels of Defense IR&D. Furthermore, the R&D budgets of US corporations are increasingly focused on near term opportunities. These combined trends threaten to eventually eliminate the technological edge that is essential if US forces are to protect US national interests, often against numerically superior forces, with politically acceptable casualties. To maintain a technological edge into the next century, DoD S&T budgets must be protected, even as the overall defense budget declines.

In order to arrest the decline in RDT&E, the first place to look is within the 20th century infrastructure to see what can be cut out of the O&M accounts (as described above). The second place to look is within the procurement accounts, which are planned to increase significantly

over the coming five years. While modernization is badly required (since it was neglected over the last decade), it would be extremely wasteful to simply update systems for the 20th century with their more modern counterpart, rather than shifting to 21st century equipment once it has been proven out. In the interim period, it is essential that some planned procurement investments be redirected toward the technologies that are needed for 21st century superiority. For example, digitization of tracked vehicles and helicopters (rather than buying additional platforms) is not currently emphasized in the five-year plan. Similarly, acquiring smart weapons now rather than additional air platforms would also appear desirable. In both of these examples, the current plan calls for such a shift in emphasis in procurement at the end of the five-year period and beyond. But history has shown that this is likely to slip out still further, unless there is a clear change in resource allocations.



This figure depicts the rebalancing required to implement the recommendations of this Summer Study. Despite uncertainties in the precise investments needed, clearly more than enough funds (by a factor of several) could be extracted from the “options” side to pay for the “investment” side. This Task Force sees the potential to dramatically increase the likelihood that US forces will maintain military superiority in the 21st Century through such a rebalancing process. Bringing such a rebalancing about will require direct involvement of the Deputy Secretary and the Under Secretary for Acquisition and Technology.

DEFENSE SCIENCE BOARD TASK FORCE ON THEATER MISSILE DEFENSE*

This report focuses on problems and deficiencies in the TMD program.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

We found substantial progress in the TMD program since the Gulf War (also since the last DSB/DPB TMD Task Force in 1991). The progress includes enhancement to fielded capabilities, investment in major new development programs and technology efforts, greater involvement by the CINCs, more joint exercises and the publication of doctrine for JTMD. We also found some problems and deficiencies which are highlighted in the following two pages along with our primary recommendations.

THREAT PROJECTIONS AND THE ACQUISITION PROCESS

We found over emphasis on evidence based threat projections and recommend that:

- USD(A&T) and the Director, DIA provide resources and increase the role for Red Teaming and threat modeling within a disciplined process to characterize threat options
- USD(A&T) direct BMDO to add cruise missiles to the ballistic missile threats it is already examining in its Red Team and Countermeasure Skunk Works activities
- BMDO prepare an annual report to USD(A&T) on the TMD Red Team results, characterizing possible threats and countermeasures according to effectiveness and difficulty and describing the strategy to deal with these threats

THE ABM TREATY AND TMD

We found TMD capabilities being constrained by the Treaty demarcation path the US had been pursuing and recommend a different approach:

- Based on demonstrated – and NTM verifiable – capabilities, achieved by not testing TMD systems against missile targets in excess of 5 km/sec and 3,000 - 3,500 km range
- Consistent with the May 1995 Clinton/Yeltsin Summit Statement
- Pursuing confidence building measures and cooperative efforts with the Russians and subsequently the Chinese

* *Report of the Defense Science Board/Defense Policy Board Task Force on Theater Missile Defense, January 1996, Unclassified. (DTIC #ADA 318537)*

ORGANIZING FOR JTMD

We found a comprehensive vision of JTMD promulgated by the Joint Staff, but no Joint CONOPS nor complementary comprehensive approach on the developers' side. To organize more effectively for JTMD, we recommend several steps including:

- Assigning USACOM the responsibility for the overall JTMD architecture
- Combining land based cruise and ballistic active theater missile defense development under BMDO

TMD PROGRAM AND ACTIVITIES

There are reasonable rationales for each of the six TBMD programs. However, substantially increased budgets for TBMD will be required to produce and deploy all of these systems. We are concerned that the massive Capstone TMD COEA effort will not produce the desired illumination of critical investment decisions.

We conclude that very low leakage, while desirable, is unlikely to be a practical TMD goal except against very small attacks. Raising the price to an adversary, while clearly not as satisfactory as denying delivery, is a worthy and practical objective for today's investment decisions.

There is insufficient attention to architectures based on distributed sensors supporting several interceptor systems.

- The advanced airborne radar sensors being developed by ARPA are crucial for defense against land attack cruise missiles and can also make important contributions to TBMD (including BPI and MEADS). We concluded that Aerostat basing could be an important complement to fixed wing A/C and recommend more effort on Aerostat design as well as moving the airborne radar technology closer to a fielded capability in order to hedge against rapid emergence of the land attack cruise missile threat.
- We recommend more aggressive pursuit of CEC-like capabilities for JTMD.

We are concerned about the fragility of hit-to-kill systems in combat and recommend more testing in realistic environments and more intelligence data collection against real targets.

We are concerned about countermeasures to descent phase TBMD and recommend more attention to boost phase intercept, with the highest priority to airborne intercept concepts.

We did not find a coherent, integrated effort to improve attack operations against mobile theater missiles. While we remain skeptical about achieving sufficient effectiveness to substitute for active defense, there are opportunities to improve on dismal past performances. We recommend the development of a comprehensive attack operations architecture and

implementation road map that makes better use of new surveillance and C³ capabilities being fielded for other purposes.

We find that passive defenses continue to be undervalued and suggest several areas for additional attention.

DEFENSE SCIENCE BOARD TASK FORCE ON STRATEGIC MOBILITY*

This Task Force examined the Joint and Service processes and resources for planning, executing, protecting and sustaining force deployments. They also researched the resources and activities that provide command and control and information systems in support of strategic mobility. The Task Force focused on five broad challenges to efficiently and effectively fulfill the strategic mobility vision. These five area are discussed below.

WHERE TO FOCUS

- Shape the force for response
 - Translating the Services' 21st Century how-to-fight concepts and capabilities into more agile, deployable combat and support forces
 - Adding deployability and agility as key factors in evaluating systems and concepts
 - Supporting initiatives for lean logistics and velocity management

DEPLOYMENT ARCHITECTURE, PLANNING, INFRASTRUCTURE AND FLOW

- Progress in fixing fort-to-port but the first 5 days are critical
- Port-to-port movement to theater PODs- C-17, Large Medium speed Roll-on/Roll-off ships (LMSR), Ready Reserve Force (RRF), prepositioning programs, and enroute airlift infrastructure.
- Improving port of debarkation throughput (port-to-foxhole)- lagging behind
- Need seamless force and support deployment system and process
- Need improved systems for execution in addition to deliberate planning systems

Those perspectives led the Task Force to focus most intensely on the areas noted below.

The Task Force did not attempt, and found no need, to invent new operational concepts to make forces more agile, adaptable and deployable. The Services are putting thought and energy into doing that, and bold concepts are currently being evaluated. The task now is to craft force structures and support concepts that go along with these bold concepts.

As to deployment flow, the emphasis clearly needs to be on the bottlenecks in mobility flow- the first five days of receipt and loading at ports of embarkation and movement through theater ports to tactical assembly areas. This will require that, in addition to increased attention to

* Report of the Defense Science Board Task Force on Strategic Mobility, August 1996, Unclassified.
(DTIC #ADA 316992)

physical capabilities, the plethora of current plans, programs, and organizations for deployment planning and execution integrate into a coherent joint deployment doctrine in a seamless manner.

MORE POINTS ON WHERE TO FOCUS

- Information system support for deployment planning and execution
 - Need for factory-to-foxhole information system- include a detailed simulation of the system and its operation
 - Need a coherent management framework for the many ongoing efforts to modernize information that facilitates:
 - Fielding state-of-the-art, near-term transition systems to ensure connectivity
 - Transition to truly modern open architecture, flexible systems
- Protecting the forces entering the theater
 - Needs greatly intensified focus
 - Expand Joint Warfare Capability Assessments (JWCAs), deployment feasibility work, exercises, etc, addressing hostile action against deployment to operations — particularly at ports
 - Need to minimize pile up of exposed forces and material at vulnerable nodes
 - Need realistic assessments of the near-term and long-term threat

Modern information systems are essential to a timely, seamless flow, and a rich menu of technology and information concepts is available and being pursued. What seems most needed is coherent direction for the interim systems and planning for the more robust, more flexible next generation systems.

It is not useful to dwell on worse case assumptions and concerns that could paralyze planning and progress in developing and fielding the needed elements of strategic deployment. It is also not acceptable to “assume away” the consequences of reasonable adversary motivations and attainable capabilities that could seriously disrupt the mobility flow to and through the theater ports. The Task Force searched diligently for interest and action in this area and was disappointed in the quality and quantity of what was found.

ONE MORE POINT TO FOCUS ON

- Lift and prepositioning capabilities
 - Continue strong support of approved programs
 - Need to accelerate the program for Sea State 3 Logistics-Over-the-Shore capabilities
 - Attention to numerous challenges in moving and handling ammunition

Current programs will, if carried to completion, provide the needed port-to-port lift.

However, deployments are heavily dependent on large, modern ports. More attention is needed on over-the-shore capabilities to supplement established ports and to reduce vulnerability to disruption.

Ammunition handling capability through the ports and in the theater needs much more attention.

TACTICS AND TECHNOLOGY FOR 21ST CENTURY MILITARY SUPERIORITY*

This Task Force explored new ways to make rapidly deployable forces much more effective than they currently are. They recommended that the concepts they described be developed into fielded capabilities over the next two decades.

SUMMARY

Unless the U.S. is able to enhance the effectiveness of the military forces that it can very rapidly bring to bear in overseas crises it will have diminishing ability to influence events and protect its interests and commitments in the 21st century.

The reasons are spelled out in the 1995 DSB Summer Study which posited 21st century regional adversaries with the motives to accomplish their military goals quickly and the means to disrupt and delay U.S. Desert Shield-type military deployments to their neighborhood. Rapid and effective application of U.S. military force can prevent bad situations from becoming much worse and a demonstrated capability may help dissuade aggression in the first place. This 1996 DSB Summer Study on Tactics and Technology for 21st Century Military Superiority was tasked to identify how to make rapidly deployable forces more potent.

Based on its analysis, this Task Force believes that substantial, possibly revolutionary, enhancements of the effectiveness of rapidly deployable military forces are feasible. We believe that the concepts we explored in this study can be refined, tested, modified, shaped and evolved into fielded capabilities over the next 10-20 years. The Task Force believes that the technology can be brought to necessary maturity to enable new CONOPS and tactics during this time within reasonable resource expenditures.

Air- and sea-based firepower alone may well be sufficient to deal with certain military challenges confronting the U.S. in the 21st century. However, for both military and geopolitical reasons, many potential future military contingencies will offer critical early roles for U.S. ground forces in theater. These roles include integrating with coalition forces, complementing remote sensors by filling in gaps and resolving ambiguities, identifying noncombatants, securing points of debarkation for follow-on forces, temporarily controlling territory, locating and neutralizing weapons of mass destruction (WMD) capabilities, and preparing to make more permanent the gains achieved by long range precision strike.

This expeditionary force concept will not deal with all future military contingencies. It would serve as a precursor force to help deter aggression, halt attacks, secure critical areas and in general prepare the way for the later arrival of more extensive forces. It could accomplish other missions, particularly those on the lower end of the conflict scale, on its own: getting in, doing the job and getting out quickly. It clearly is not intended for major offensive ground campaigns although the sort of rapidly deployable military capability we envision would contribute to avoiding the need to conduct such campaigns. The concept borrows features associated with

* Report of the Defense Science Board 1996 Summer Study Task Force on Tactics and Technologies for 21st Century Military Superiority, Volume I, October 1996, Unclassified. (DTIC #ADA 318788)

Special Operations Forces (SOF) but its operations would in general be of a much larger scale than the SOF's and be overt rather than covert.

The Task Force's concept exploits the enormous and barely scratched potential of emerging capabilities to provide theater wide situation understanding, effective remote fires and a robust interconnected information infrastructure. We use the term "situation understanding" throughout this report to represent the higher order knowledge obtained when situation awareness is combined with appropriate context and training.

We envision the integration of these capabilities with a ground force redesigned from the bottom up, starting with the "combat cell," the smallest warfighting unit. The resultant ground force would be comprised of 10-20+ man light, agile combat cells and, depending on the operational environment, a heliborne armed reconnaissance capability. Such combat cells would operate in highly dispersed postures, presenting few concentrated targets for the enemy. The combat cells could also coalesce into larger units when necessary. Initial analysis suggests that equipping the cells with organic vehicles significantly enhances their effectiveness and survivability. Stealth, situation understanding and information warfare will be vital ingredients in their survival kit. The concepts also call for extensive use of unmanned vehicles and robotics, and it relies on a substantially reduced logistical footprint.

The Task Force believes considerably more attention to these ground combat cells is warranted. Light infantry, getting relatively little notice and resources from the Pentagon, has not changed much in capability over many decades but has great potential for enhancement if enabled by new tactics and technology.

A joint and distributed expeditionary task force — comprised of light and agile ground and air combat cells coupled to remote suites of sensors, weapons and information processors — can be a potent military force, able to take on missions (at least for limited duration) now requiring much larger and heavier forces on the ground:

- **New levels of situation understanding are necessary to enable effective remote fires and ground operations in widely dispersed postures.** It can be provided by sensor and information management suites able to do for the ground war what the Cooperative Engagement Capability (CEC), is beginning to do for the fleet air defense. The goal is to provide a comprehensive, shared, fire control (and combat identification) quality picture of the ground environment. The picture is derived by fusing the data (high resolution, multispectral, geometrically diverse) from multiple sensors on a variety of platforms from satellites, aircraft and unmanned aerial vehicles (UAVs) to unattended ground sensors and micro air vehicles. Management of this diverse sensor suite and the information it produces will become a critical task for future theater and battlefield commanders. Traditional distinctions between intelligence and tactical surveillance will disappear.
- **This new expeditionary force will be dependent on remote fires that are effective against a variety of targets.** It will not be sufficient to merely rebase historical weights and rates of fire. The fire must be made much more efficient and the demand for emergency fire must be reduced. The keys to accomplishing these are affordable

precision weapons and greatly enhanced situation understanding which will turn today's fleeting observations into tomorrow's tracked targets. With the appropriate ensemble of weapons, this will permit us to attack the enemy when he is most valuable and most vulnerable. Shortening the time of flight of the remote weapons will not, by itself, provide the requisite responsiveness and, thus, there will be important roles for loitering weapons and in-flight updates to incoming weapons. The remote fires could be delivered by land-based tactical aircraft if the bases are available and more generally by bombers and sea-based aircraft, missiles and long range guns. We envision an important role for armed UAVs as well

- **A necessary foundation for this concept is a robust information infrastructure.** It must not only provide secure communication among the distributed participants but also geographical location, precise time, telemedicine and other functions. The multitiered communication network makes use of geosynchronous and low earth orbit satellites, aircraft and UAVs. The ground combatants' portal into this infrastructure will be a personal information ensemble based on commercial cellular technologies, able to provide paging, conferencing and even imaging services. Intelligent software agents will help manage both the operation of the network and the applications of the information that flows through it.
- **The robust wide band communication networks and enhanced situation understanding offer the potential for both more centralized control (the CINC can see "everything") and more decentralized empowerment (the combat cell commander can see what the CINC sees).** These capabilities can present future commanders both opportunities to exploit and tensions to resolve. A major challenge will be the exploration of the command relationships that best take advantage of these additional degrees of freedom. We will not be able to eliminate the fog of war. We can, however, provide the tools and training to help the combatants, from Joint Task Force commander to combat cell member, better deal with the uncertainty and chaos that will remain intrinsic to combat.

The Task Force explored and analyzed the concept in several environments — halting combined arms attacks, controlling territory in the presence of hostile militia and conducting operations in urban terrain. The results are discussed in the report and more detail is provided in Volume 2. While we do not expect that we got all or even most of the details right, they provide a starting point for further development and experimentation. The report also provides more detail on the systems and associated concepts of operation needed to provide the situation understanding, remote fires, information infrastructure and force insertion, extraction, sustainment and survivability. The substantial implications for training these expeditionary and dispersed force concepts are also discussed.

Several necessary conditions for the sort of revolutionary changes we envisage are already in place:

- **There is a compelling strategic rationale,**
- **The enabling technologies are maturing rapidly and,**

- **There are efforts now underway within the Services to explore such new warfighting concepts.**

What is missing are the organizations and processes necessary to test and evolve joint warfighting architectures for new concepts such as the distributed, expeditionary force concept proposed here: agile ground combat cells, coupled to ensembles of distributed remote sensors and precision weapons, all interconnected by a robust information infrastructure and supported by smart logistics techniques.

The Task Force offers three sets of recommendations. The most important is to establish a joint effort and a “try before buy” environment to pursue these concepts. The joint effort, sponsored by the Secretary of Defense and the Chairman, JCS, would develop, test, analyze, and evolve these concepts through a series of experiments (to learn, not prove), supported by refocused simulation and analysis capabilities. Our adversaries will surely work hard and creatively to expose potential vulnerabilities in the distributed force concept. Furthermore, they will have access to much of the same technology that enables the concept. Their countermeasures will call for counter-countermeasures. Some of their responses may limit the applicability of the concept, others could prove to be more damaging to its basic viability. An energetic Red Team must be an integral part of the process to explore and develop these new warfighting concepts.

The second set of recommendations calls for support of critical enabling systems and mechanisms — many already ongoing, others new. These include making the USD(A&T) and the ASD (C³I) the enforcers of the joint technical information architecture and providing funds to equip some of our light infantry forces with modern communication, navigation and targeting technology. The third set of recommendations calls for the establishment by 1998 of a joint operational task force to be the primary recipient of the products — tactics and technology — that evolve from the above efforts.

At the very least, pursuit of these concepts will yield potent multipliers for “standard” forces and tactics. There is a good chance that we can achieve dramatic increases in the effectiveness of rapidly deployable forces if redesigning the ground forces around the enhanced combat cell proves to be robust in many environments. There is some chance that all this will amount to a true revolution in military affairs by “eliminating the reliance of our forces on the logistics head as Blitzkrieg freed the offense after World War I from its then decades old reliance on the railhead.”¹

¹ From a presentation to the DSB Task Force by MG Robert H. Scales, USA, entitled “Modern Land Warfare Follows Technology Driven Cycles.”

DEFENSE SCIENCE BOARD 1996 SUMMER STUDY ON ACHIEVING AND INNOVATIVE SUPPORT STRUCTURE FOR 21ST CENTURY MILITARY SUPERIORITY*

As seen in Figure ES-1, with a declining defense budget, the DoD has found it increasingly difficult to provide adequate funds to satisfy 21st Century equipment modernization requirements (procurement has declined over 70% since 1985). Support and infrastructure costs have been taking an increasing share of DoD resources (absorbing over 55% of the budget, as shown by the white areas in figure ES-2), with fewer dollars available for combat and modernization (as shown by the shaded areas in Figure ES-2).

**DoD Total Obligational Authority
(TOA) 1983-1997**

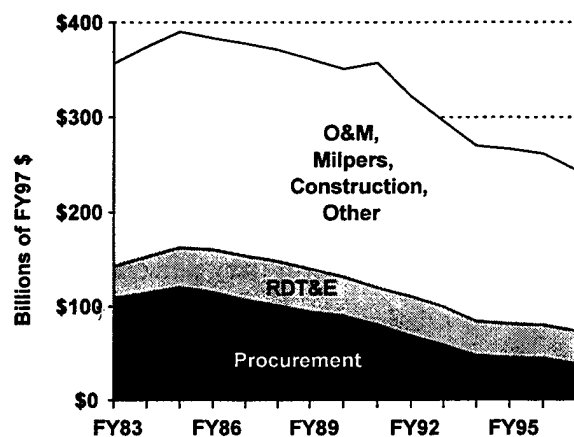


Figure ES-1

Total Expenditures 1996

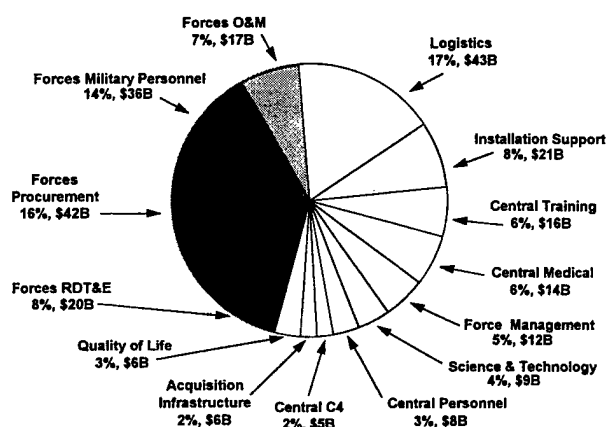


Figure ES-2

The 1996 Defense Science Board Summer Study on Innovative Support Structures for the 21st Century was charged to assess current DoD support and to recommend approaches for both enhancing performance and reducing costs. This Task Force focused its energy on identifying 1) specific approaches for lowering support costs and enhancing performance, and 2) mechanisms for implementation of needed changes (to shift dollars from support to modernization and combat capability).

The DoD currently has plans to significantly increase its expenditures on modernization. However, this Task Force found that these investment plans have a very high risk. It is likely that resources will not be available for needed investments in modernization, due to the escalating costs of support and the associated infrastructure at a time when budgets are not correspondingly increasing. Historical trends show increasing support costs coupled with poor support responsiveness.

* Report of the Defense Science Board 1996 Summer Study Task Force on Achieving an Innovative Support Structure for 21st Century Military Superiority, November 1996, Unclassified. (DTIC #ADA 320394)

The Task Force concluded that a very different approach to providing support is required in order to ensure the availability of funds for modernization and combat capability within the likely total DoD resources. Based on analysis of both the Department's and private sector approaches, this Task Force sees the opportunity to enhance military support while significantly shifting funds from support to combat effectiveness and modernization. The challenge facing the Department is to achieve such a dramatic transformation over the next five years.

The Task Force recommends two fundamental changes for DoD:

- Generating significantly more dollars for combat capability and modernization through cost reductions in specific high cost areas of support, while providing higher quality, more responsive support services to the warfighter and;
- Creating a planning and budgeting process that will have incentives to more effectively align overall DoD resources with DoD's mission requirements.

Each of the support areas shown in Figure ES-3 have been analyzed in detail for their costs, personnel and potential for change. Specific recommendations are made by this Task Force that, if implemented, could yield shifts of over \$30B per year from support to forces by the year 2002. Essential to achieving these changes is a dramatic increase in outsourcing of the majority of support functions to the competitive private sector and a corresponding reduction in DoD civilian and military personnel. Specifically, over the next five years, the Task Force calls for a ~5% per year reduction in the civilian workforce and a ~2% per year reduction in military personnel.

Figure ES-3 illustrates both the relative payoff and the relative difficulty of achieving the specific cost reduction recommendations of this Task Force. Although challenging to achieve, this Task Force strongly believes that an integrated, DoD-wide approach to shifting support costs to modernization and combat, combined with exploitation of modern approaches (often based on advanced information technology) that yield better performance for lower costs, can be implemented within a 5 year period. But, DoD's civilian and military leadership must create a vision for such an integrated approach and aggressively pursue various cost reduction approaches (e.g., widespread use of the private sector for competitive outsourcing) in spite of the difficulty of achieving the required change.

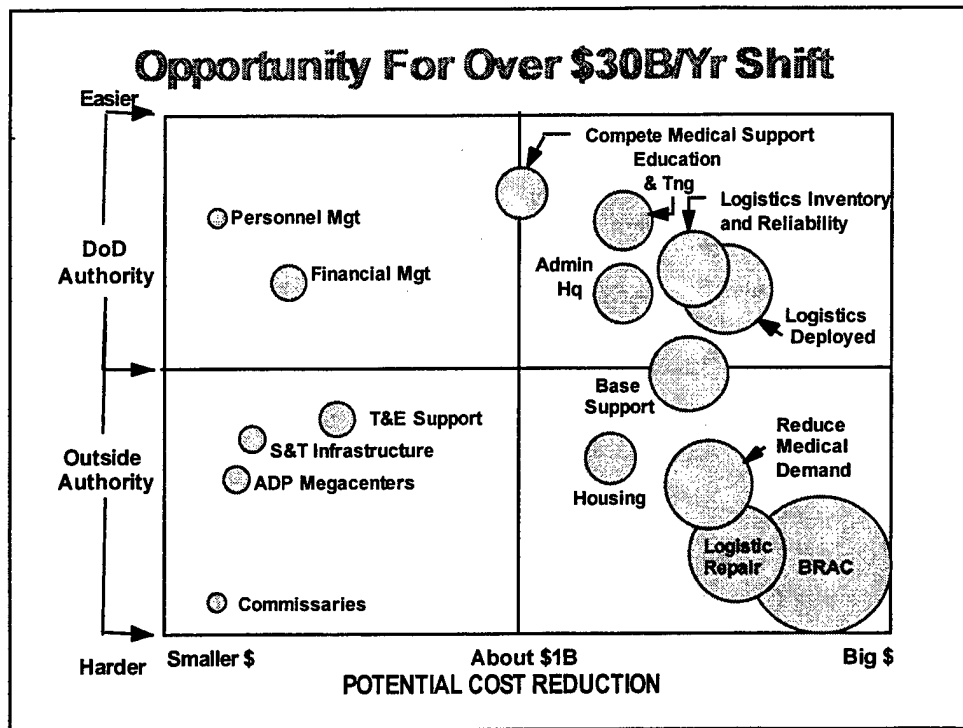


Figure ES-3

Further, the Task Force sees the “mission pull” process depicted in Figure ES-4 as the other essential part of such an integrated approach. The essential step is getting the “users” (the warfighting CINCs) directly involved in setting priorities within the resource planning process (through the CJCS/VCJCS). While the Services, as the “suppliers,” would still have full responsibility for the resources, the trades between “support” vs. “modernization and combat capability” (within a constrained total budget) would now be driven by mission needs (vs. supplier desires).

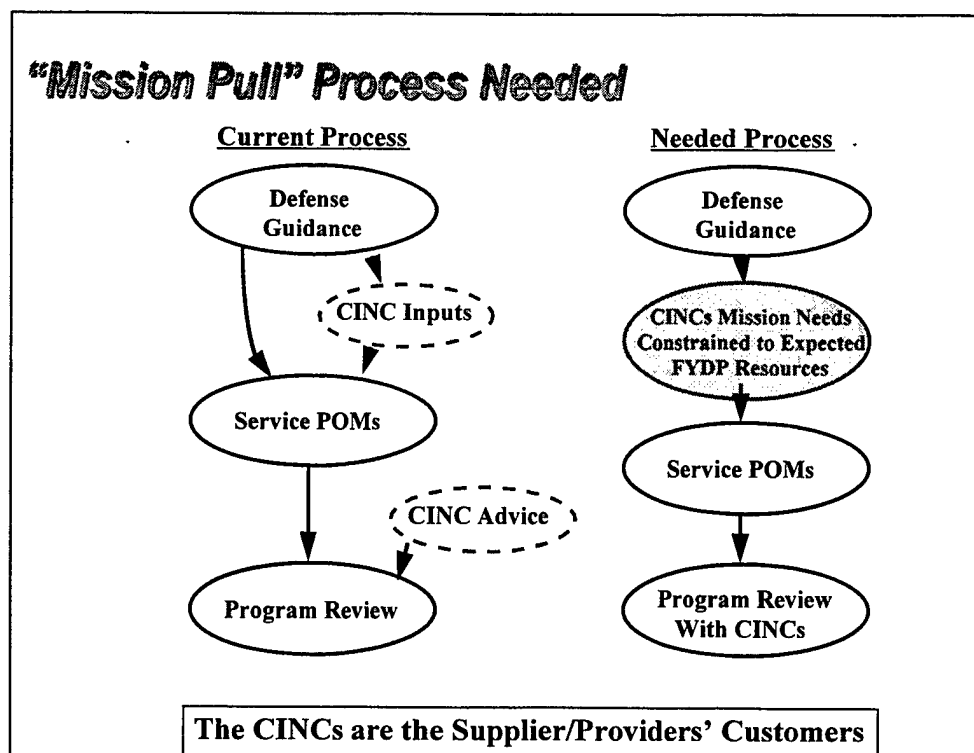


Figure ES-4

To achieve the required transformation in DoD resource allocations, there are a variety of barriers to change that must be overcome. To begin with, today there is no explicit vision, goals or metrics for embarking down a path of shifting resources from support to modernization. This Task Force proposes a vision that unambiguously places public sector employees only in “inherently governmental” functions, (their core competencies: warfighting, direct battlefield support, decision policy making, and oversight), while the competitive private sector will perform all other functions (its core competencies). The Secretary should adopt this vision and establish quantitative dollar objectives and performance metrics for measuring progress in implementation.

In terms of the recommendation for a specific policy shift by the Department toward the DoD only performing “inherently governmental” functions, it would be beneficial to support Senate Bill 1724 and the House equivalent, House Bill HR 28. While these bills are not expected to pass during the present session, there would be a much better chance of their being approved with DoD support. They are in line with what this Task Force is recommending and indicate some Congressional support for the Task Force recommendation.

Secondly, the Department must change the perverse incentive system currently in place that encourages managers at all levels to maintain the status quo and even to make changes in less cost-effective directions. The Department’s resource allocation processes, authorities and responsibilities must become aligned with missions and not with “Cold War” functionalities. The Department must shift from “supplier” budgets to “user” budgets, with the CINCs playing a key role in budget priorities, within the overall guidance provided by the Secretary and with integration of the CINCs inputs by the CJCS/VJCS. Additionally, to create individual

incentives, when commanders make cost savings, their organizations should be rewarded by keeping a share of the money for future investments.

To complement these steps, the Department must make sufficient up-front investment resources available to "kick start" the dramatic shifts from support to combat effectiveness and modernization. The cost associated with each of the early rounds of BRAC were significant. Resources must be made available for future BRACs as well as for other needed investments. This Task Force strongly encourages the Department to set up an investment pool for use in encouraging high rate-of-return investments that will lead to dramatic shifts of resources from support to modernization and combat effectiveness.

The DoD financial system must also be strengthened. Managers within DoD must be able to gain better visibility on costs vs. outputs in the support functional areas. The current financial system encourages mislabeling, evasion of responsibility, looking good vs. being good and distrust of senior DoD executives. The Task Force feels that widespread use of activity-based-costing is appropriate; however, the recommendation is to make the needed financial system changes in parallel with the overall support area transformation not to hold up the latter until the former is complete.

Finally, DoD must convince Congressional leadership that the dramatic shift of resources outlined within this report is crucial to the long term military superiority of the US, and that such a shift can be accomplished within likely budgets, even under balanced budget and lower tax environments. The plan to convince Congressional leaders of the need for this shift should be of high quality, inclusive and provide a high (>90%) probability of success - in other words, as good as operations plans in the military are supposed to be. Currently, there is no integrated plan of any quality that is comprehensive and provides any assurance of success. This is normally thought of as a serious failure on the part of executive management.

The Secretary must employ both military and civilian leaders of the Department in this process and gain the support of industry leaders (who will benefit from the increased outsourcing). There is a need for a commonality of vision across the DoD.

In summary, the Secretary should seize the opportunity now to start this process. The leadership team in place today is ideally suited to the task. DoD should:

- State a new support vision and goals for cost reduction and performance enhancement;
- Create a new defense planning and budgeting process, with overall resource allocation and priority setting strongly influenced by the CINCs; and
- Assign responsibilities and begin the detailed implementations process this year.

It is important to emphasize the critical nature of the timing associated with taking these actions. The implementation of the Task Force recommendations is a multi-year effort. It is highly desirable that the current Secretary initiate this process over the next few months, so that the implementation gains an initial momentum.

REPORT OF THE DEFENSE SCIENCE BOARD TASK FORCE ON INFORMATION WARFARE-DEFENSE*

The Task Force concluded that there is a need for extraordinary action to deal with the present and emerging challenges of defending against possible information warfare attacks on facilities, information, information systems, and networks of the United States which would seriously affect the ability of the Department of Defense to carry out its assigned missions and functions. We have observed an increasing dependency on the Defense Information Infrastructure and increasing doctrinal assumptions regarding the continued availability of that infrastructure. This dependency and these assumptions are ingredients in a recipe for a national security disaster.

Accordingly, we recommend a series of over 50 actions designed to better prepare the Department for this new form of warfare beginning with identification of an accountable focal point within the Department for all IW activities and ending with the allocation or reallocation of approximately \$3 billion over the next 5 years to implement these recommended actions.

RECOMMENDATIONS

The Task Force makes 13 key recommendations and considers these recommendations as *imperatives*.

Bottom Line - DoD has an urgent need to:

1. Designate an accountable IW focal point
2. Organize for IW-D
3. Increase awareness
4. Assess infrastructure dependencies and vulnerabilities
5. Define threat conditions and responses
6. Assess IW-D readiness
7. "Raise the bar" (with high-payoff, low-cost items)
8. Establish a minimum essential information infrastructure
9. Focus the R&D
10. Staff for success
11. Resolve the legal issues
12. Participate fully in critical infrastructure protection
13. Provide the resources

* *Report of the Defense Science Task Force on Information Warfare Defense*, November 1996, Unclassified. (DTIC #ADA 319571)

In addition, the Task Force made over 50 additional recommendations, which are categorized under these key recommendations. (Note that the first recommendation addresses all of information warfare, not just defensive information warfare.) The Task Force attempted to prioritize these "key recommendations," but in the end decided that portions of all of these key recommendations should be implemented immediately.

***DEFENSE SCIENCE BOARD TASK FORCE ON COMMAND, CONTROL,
COMMUNICATIONS, COMPUTERS, INTELLIGENCE, SURVEILLANCE AND
RECONNAISSANCE (C4ISR) INTEGRATION****

This Task Force focused its attention on its concern that joint force commanders do not have a strong enough influence on decisions regarding what increased (or decreased) C4ISR capabilities are needed for them to carry out their assigned missions. The Task Force achieved a consensus on the need for improvement in two areas:

1. A joint process for determining what a joint force commander needs in C4ISR systems and related weapon systems and support capabilities in order to operate effectively. The Task Force sees the need for a more formal joint process on the front end of the programming and budgeting cycle. The Task Force does not yet see a comprehensive, institutionalized process that provides:
 - Adequate support to enable the CINCs to stay abreast of ongoing and potential development of capabilities that can significantly influence the CINC's ability to perform their missions
 - Ways to test new concepts and systems and an exercise and training environment that helps assure continuing C4ISR competence
 - An effective formal process which allows the Joint elements of DoD to influence the organization, training and equipping allocations that produce capabilities to support the CINC's assigned missions
2. A military systems engineering capability for C4ISR integration. The Task Force believes that DoD lacks a joint mechanism for the design and improvement of the C4ISR system. The Service Components develop their own C4ISR systems and subsystems based on their own operational concepts and view of the operational need. These several systems are brought together in a theater when needed and great time and effort is then expended to make them work together well enough for the forces to operate jointly in an adequate manner. Some progress is being made, but too slowly to meet immediate needs and seize the opportunities for improvement. DoD must do better in the planning, design and execution of joint C4ISR integration. The part of DoD that is responsible for joint activities consists of the CJCS, the Joint Staff and the CINCs. Up until now, the CINCs have been operating organizations and joint activities are not responsible for the systems engineering and design of the CINC's military capability. To take on C4ISR integration responsibilities, not only must some joint entity be given the formal responsibility, but it must be provided with the resources needed to carry out this job.

* Report of the Defense Science Board Task Force on Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Integration, February 1997, Unclassified. (DTIC # ADA 326142)

Task Force recommends that SecDef and the Chairman continue to evolve the joint process for determining what a joint force commander needs in order to operate effectively as recommended in the 1996 DSB Summer Study on Innovative Support Structure for 21st Century Military Operations. Given its inherent joint character, C⁴ISR integration is a logical aspect of warfare for this joint process to focus on early

The Task Force recommends that the SECDEF and the Chairman create a military systems engineering organization to support the CINCs in their evolving responsibility for the operational design of joint C⁴ISR. The DoD initiative in Joint Theater Air and Missile Defense assigns the responsibility for systems engineering to BMDO. This new structure is consistent with this recommendation and is an appropriate, although partial step in the direction needed for the broader joint C⁴ISR area. This Task Force endorses this step, particularly in its apparent effort to involve the CINCs in a "military systems engineering" effort. The Task Force recommends that CJCS use the new structure that was established to provide joint operational architectures and joint system engineering to Joint Theater Air and Missile Defense as a pilot program for the broader C⁴ISR area, with focus on the refining the responsibilities and missions of warfighting CINCs.

The Task Force recommends that the Department work with the DCI and the broader Intelligence Community to develop new ways of providing information support for operational commanders which effectively and efficiently integrate the rich array of assets available within the United States. As a mechanism to facilitate identification and implementation of good ideas for C⁴ISR integration, the DoD might consider the creation of a C⁴ISR Integration Review Board, similar to the newly formed Space Management Board and at the same level (DASD chair in the name of the SecDef/DepSecDef with the VCJCS, DDCI and other actors represented). Today's information technology can support revolutionary changes in how support is provided to military operators. DoD needs mechanisms that facilitate the introduction of such revolutionary changes into warfighting capability.

The Department should closely evaluate whether the separation of intelligence and operations functions within warfighting elements continues to serve the nation well.

DEFENSE SCIENCE BOARD TASK FORCE ON GPS — PHASE II*

The Defense Science Board (DSB) Task Force on GPS-Phase II was a follow-on activity to the 1995 Task Force on the Global Positioning System (GPS).

The Task Force addressed a set of questions relating to the affordability of future military GPS user equipment (GPS receivers) in view of the need for significant antijamming enhancements. Military navigation means other than GPS were considered. A pseudolite approach to enhancing GPS antijam capability was considered. The ten year duration NAVWAR plan developed by the GPS Joint Program Office was reviewed by the Task Force.

The Task Force concluded that there was no attractive alternate form of military navigation relative to the GPS-internal combination, which is increasingly permeating all military platforms. Pseudolite enhancements may be quite useful in some specialized applications but they should not constitute our main approach to a robust antijamming capability. The Task Force reiterated from its earlier study that spatial (antenna) rejection of jamming still appeared to be the most appropriate and efficient way to achieve a substantial degree of protection against jammers.

The Task Force supported the DoD NAVWAR plan, but made suggestions for the addition of other initiatives to the national effort on GPS not covered in NAVWAR.

The Task Force chose to make its recommendations in the form of some questions and answers.

Question (Q): What is the right navigation approach for the future?

Answer (A): GPS/INS

Q: What about GPS Jamming Vulnerability?

A: Fix it!

- Spatial A/J
- Advanced Digital Receivers
- Pseudolite Approaches
- Jammer Killers
- Next Generation GPS

Q: Is the NAVWAR plan the right plan?

A: Yes. Support it, but:

- Protect against possible failure modes
- Augment it with a R&D program

First, what is the right navigation approach for the future? We continue to feel the GPS/INS technique is the only viable approach given the unique strengths and advantages of GPS. There is simply no other alternative at this time.

With regard to the jamming vulnerability of GPS, we argue "Fix It"! We have invested some \$12 billion in the development of the GPS system to date, yet have invested a relative pittance in antijamming research and development. Not only have we not given it the "old college try", we have barely scratched the surface in antijam technology. Modern electronics offers great hope here and it should not be too difficult to drive the enemy cost of jamming very high.

NAVWAR must be supported, but we should not be so naïve to assume government plans will work out just fine. The DoD support to NAVWAR should include provisions and augmentations such that the Nation has a robust approach for military navigation, one which is effective for both the near term and the distant future.

DEFENSE SCIENCE BOARD SUMMER STUDY 1997 DoD RESPONSES TO TRANSNATIONAL THREATS*

This Defense Science Board study on DoD responses to transnational threats principally addresses DoD capabilities, options, and responses to transnational threats. It recommends a long-term strategy for DoD's response that leverages the Department's resources and strengths.

The task force concludes that transnational threats can be as serious as those of a major military conflict. Combating transnational threats is part of the Department of Defense's core business, and DoD can meet these challenges using existing policies and organizations. An effective national response to the transnational threat and implementation of the six-element strategy requires a dedicated effort on the part of the national leadership to include senior leadership in the Department of Defense, Department of Justice, Federal Emergency Management Agency, and other Federal Agencies. Such an integrated, focused, and committed response will prepare the Department and the Nation to defeat the transnational threat.

The task force has studied the issues surrounding transnational threats and made recommendations for a DoD response that includes six elements:

1. Treat transnational threats as a major DoD mission
2. Use the existing national security structure and processes
3. Define an end-to-end operational concept and system-of-systems structure
4. Provide an interactive global information system on transnational threats
5. Address needs that have long been viewed as "too hard"
6. Leverage worldwide force protection and civil protection

This task force asserts that an effective national response to the transnational threat and implementation of the six-element strategy requires a dedicated effort on the part of the President and senior leadership in the Department of Defense. To this end, the task force has identified a series of actions on which this senior leadership should focus.

The President should:

- Raise the emphasis on countering transnational threats in DoD, across the government, and with international coalition partner nations.
- Create an initiative to raise awareness of the importance of addressing nuclear, chemical, and in particular, biological warfare challenges.

The Secretary of Defense should:

* Report of the Defense Science Board 1997 Summer Study Task Force on DoD Responses to Transnational Threats, Volume I, October 1997, Unclassified. (DTIC #ADA 333273)

- Treat countering transnational threats with the same emphasis as major military conflicts. As such:
 - Assign responsibility for transnational missions with greater clarity and assign, to a single policy office, responsibility for counterterrorism, counterproliferation, transnational threats and infrastructure protection.
 - Develop an architecture defining an end-to-end operational concept and a system-of-systems structure.
 - Elevate the priority of force protection plans and programs – in the departmental guidance and in the requirements and budget processes.
 - Direct the Under Secretary of Defense for Acquisition and Technology to develop the secure transnational threat interactive information system with the involvement of key federal, state, local, and international departments and agencies.
 - Define and develop an expanded set of initiatives, in cooperation with the Secretary of Energy, to address solutions for mitigating nuclear, chemical, biological, and information warfare threats.
 - Direct the Army to develop a plan to expand the scope of and institutionalize the Nunn-Lugar-Domenici program.
 - Direct the Army and the National Guard Bureau to establish a national consequence management capability within the National Guard to support state and local agency responses to domestic chemical and biological incidents and to support the regional combatant commanders' Joint Task Force, when appropriate.

The Chairman should:

- Establish a Task Force within the Joint Staff to develop operational and systems concepts and architecture.
- Assign responsibilities for the military services to address requirements associated with transnational threats.
- Assign responsibilities for updating all operational plans for addressing transnational threats such that they include contingency planning, crisis response, and consequence management responsibilities.

The Under Secretary of Defense for Acquisition and Technology should:

- Establish a joint Technical Support Team that will provide analytical capabilities to support the Chairman in the development of a system-of-systems structure and architecture.
- Implement technology and acquisition programs which focus on mitigating "too-hard" problems.

DEFENSE SCIENCE BOARD SUMMER STUDY 1998 LOGISTICS TRANSFORMATION*

The 1998 Defense Science Board Logistics Transformation Summer Study was tasked to recommend actions to be taken that achieve “a true transformation – not marginal improvements” to the U.S. military logistics system. The DSB defines a “transformation in military logistics” as “a marked change in the nature and form of the structure and processes that equip, deploy and sustain military operations.”

The DSB Summer Study on DOD Logistics Transformation emphasizes seven points:

- As concluded in the Joint Operations superiority Summer Study, the principal operational challenge facing the U.S. military in the 21st Century is strengthening and preserving its capability for early, then continuous, application of dominant control effects across the full spectrum of conflict.
- The military logistics system is a critical enabler of deployment, then sustainment, of dominant full spectrum engagement effects.
- Today’s U.S. military suffers from a separation of logistics from operations, an organizational principle of long standing, and a reliance on mass, rather than efficiency and certainty, to be effective. As now configured, the logistics system frequently constrains operations and drains scarce resources needed for force modernization.
- Failure to seamlessly blend military logistics with operations will be a showstopper for DOD’s planned “Revolution in Military Affairs (RMA)” – a motivation that demands immediate action.
- DOD must recognize that logistics transformation is a “BIG DEAL . . . a VERY BIG DEAL.” Continuing to regard logistics as the secondary “tail” to warfighter doctrine, training and armament will have unacceptable consequences in the 21st century battlespace resulting in decreased ability to achieve national security objectives and cost.
- The military logistics system can be reformed. A “Transformed Logistics System” can be responsive to CINC (Joint Task Force Commander) needs, support rapid closure of combat power, permit a smaller footprint – both people and equipment, be more agile, responsive and survivable than today’s system, fully integrate business processes and information systems, be well integrated with industry, and be significantly less expensive.

Transformation of the military logistics system is not held up by knowledge of what to do, not primarily a structural issue, nor is it limited by lack of people, technology or resources. Instead, the most significant barrier to logistics change to meet 21st century needs is the lack of

* *Report of the Defense Science Board Summer Study Task Force on DoD Logistics Transformation, Volume I, December 1998, Unclassified.*

an overall business and information systems architecture focal point – a “champion (in the Arthurian sense).

The study’s findings and recommendations are spelled out in five areas:

- Unified and specified CINCs are unable to perform their Title 10 responsibilities to plan and manage theater logistics. CINCs must be able to “pull” required support from the logistics system.
- DOD’s logistics system is fragmented with no end-to-end control, integration, performance measures and accountability. Transformation of logistics business and information systems must be led by a Logistics Systems Architect with power to define and enforce an integrated system.
- Deployment and sustainment methods and equipment must change. Ability to deploy in undeveloped areas and under unfavorable conditions must improve; better use of commercial capability is needed.
- Decreasing logistics demand is a major element of cutting cost and improving flexibility. Force structure and weapons systems and equipment must be upgraded to reduce consumption.
- Logistics vulnerabilities need more attention. Exercises and plans must anticipate and deal with physical and information attacks on the logistics system.

CHAPTER 7.

A Space Roadmap for the 21st Century Aerospace Force

CHAPTER 7.

A Space Roadmap for the 21st Century Aerospace Force

The United States Air Force is today an air and space force whose core competencies, as articulated in *Global Engagement*,² entail the integrated employment of weapon and support systems across the physical media of air and space. But that force is largely a legacy of the Cold War, it often treats air and space operations as separate activities, and it faces wrenching changes in evolving to deal with the very different world of the 21st century. Among the basic forces that drive decisions from doctrine to system acquisition are:

- Tremendous uncertainty and variability in the situations calling for military action to support national objectives, across the full spectrum of conflict and at any place on the globe
- Continuing withdrawal from forward basing and rapid change to a continental United States-based, globally committed expeditionary force
- A military budget climate characterized by a stringency that has not been seen since before World War II, at a time when significant changes and upgrades in force structure are needed
- Persistent problems with personnel shortages, high operational tempo, aging weapon systems, and archaic information infrastructure, at least some of which are potentially addressable by migrating functions to space
- Levels of growth, diversity and maturity in commercial space enterprises that consistently outpace the most optimistic forecasts and thereby create an entirely new environment for providing important military capabilities
- The loss of Department of Defense (DoD) and Air Force leverage over commercial space operations, both in determining system capabilities and in being seen as a primary customer
- A long-term trend under which a growing fraction of Air Force resources go to provide services to others rather than to the direct warfighting mission

The future relevance and success of the Air Force—indeed, its ability to remain a preferred instrument of national power in this complex and uncertain emerging world—depend critically on becoming an integrated aerospace force which can execute the responsibilities assigned to it under *Joint Vision 2010* (JV2010).³ The essential capabilities of such a force are concisely expressed as Global Knowledge, Global Reach, and Global Power.

² *Global Engagement: A Vision for the 21st Century Air Force*, Secretary of the Air Force S. Widnall and Chief of Staff of the Air Force Gen R. Fogleman.

³ *Joint Vision 2010*, Gen John M. Shalikashvili, Chairman of the Joint Chiefs of Staff, 1996.

GLOBAL KNOWLEDGE

JV2010 depends on information dominance to enable virtually every aspect of military superiority. The heart of this capability is a system of systems. It starts with intelligence, surveillance, and reconnaissance (ISR), coupled with real-time communications and information processing. The result, from initial collection of data to its timely use by warfighters, is victory through knowing more and knowing it sooner than the enemy.

Today's Capability. Intelligence satellites and airborne platforms provide localized and generally discontinuous sensing, often impeded by weather, terrain, and hostile countermeasures. Processing and dissemination of time-sensitive data to warfighters is improving but still falls far short of the true need.

Tomorrow's Promise. The aerospace force can and must deliver precise, global situational awareness to commanders and fighters at all levels, providing the right information at the right place and time, while overcoming countermeasures and denying similar knowledge to the enemy.

Global Reach

The nation requires global presence to influence events and defend American interests, but with much less of the traditional forward basing. The mobility of aerospace forces is the key to rapid response and to the projection of all kinds of military power from U.S. bases to worldwide contingencies.

Today's Capability. Airlifters and tankers allow expeditionary forces to deploy and are engaged every day in missions from humanitarian relief to combat force sustainment. However, lift is limited, deployments take days to weeks, and success often depends on support from countries in the regions of interest—support that cannot be guaranteed in times of crisis.

Tomorrow's Promise. The aerospace force, with the right organization, training, and equipment, could deliver precisely calibrated effects, from taking a picture to dropping a precision munition, anywhere on earth, in less than an hour from the “go” order, with surprise and immunity to most defenses. Larger-scale deployments would be lighter, faster, and more effective, and the need to station forces in foreign theaters would be greatly reduced.

Global Power

America's military forces must be able to prevail in operations anywhere on earth, ranging from disaster relief to hostage rescue to shows of force and, when required, combat.

Today's Capability. Modern fighters and bombers with steadily improving precision targeting and munitions have impressive ability to prosecute targets with economy of force and greatly reduced collateral damage and casualties. However, proliferating air defenses threaten their survivability, and almost any adversary has or can have the ability to use space-based systems, eroding a long-term U.S. advantage.

Tomorrow's Promise. The aerospace force can and must enable the full richness of the “effects-based targeting” concept,⁴ using a wide range of lethal and nonlethal means to shape the desired end state of any conflict. At the same time, real space control, including assured access

⁴ “The Road Less Traveled,” Briefing by Lt Gen Gamble, 1998.

for friendly forces and denial of the same to enemies, can restore the decisive edge in space operations.

The challenge facing the Air Force is summarized in Figure ES-1,⁵ which shows the overarching operational and infrastructure tenets of *JV2010*, the Air Force core competencies which address those tenets, and the ultimate vision of Full Spectrum Dominance. A major conclusion of this study is that the Air Force can achieve *genuinely revolutionary capabilities* which make *JV2010* achievable and which offer unprecedented options for achieving national objectives.

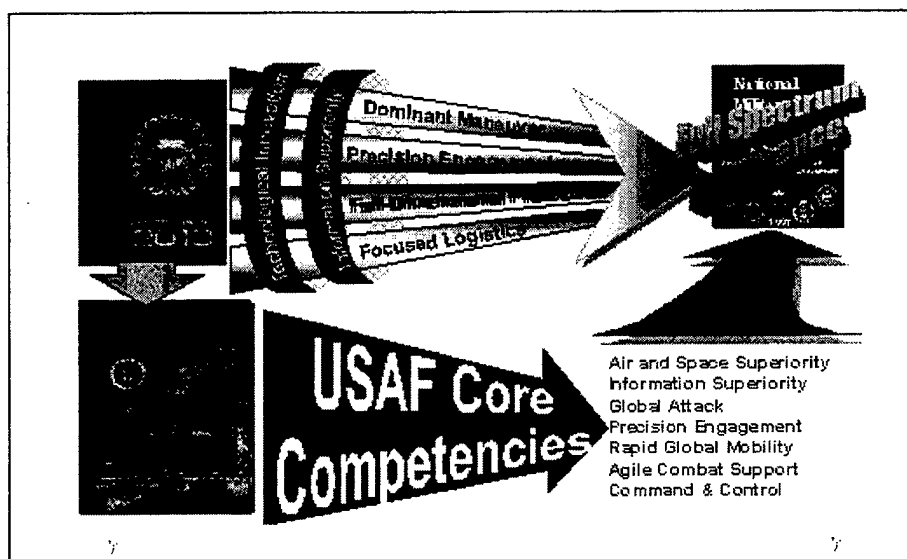


Figure ES-1. The Challenge Facing Aerospace Forces in the 21st Century Is to Develop and Apply Core Competencies That Effectively Implement National Military Policy

A REVOLUTION IN AEROSPACE POWER

In this study, the U.S. Air Force Scientific Advisory Board (SAB) examined the future capabilities and uses of aerospace forces and the courses of action available to the Air Force to achieve advances which are essential to its continued effectiveness. Two examples illustrate the great potential of integrated aerospace power. Figure ES-2 sketches a scenario for precision strike of a terrorist enclave or other time-critical target. It is based on a system capable of

⁵ "The Air Force After Next ... Is Now," Briefing to the National Defense Review, Brig Gen Wald, 1998.

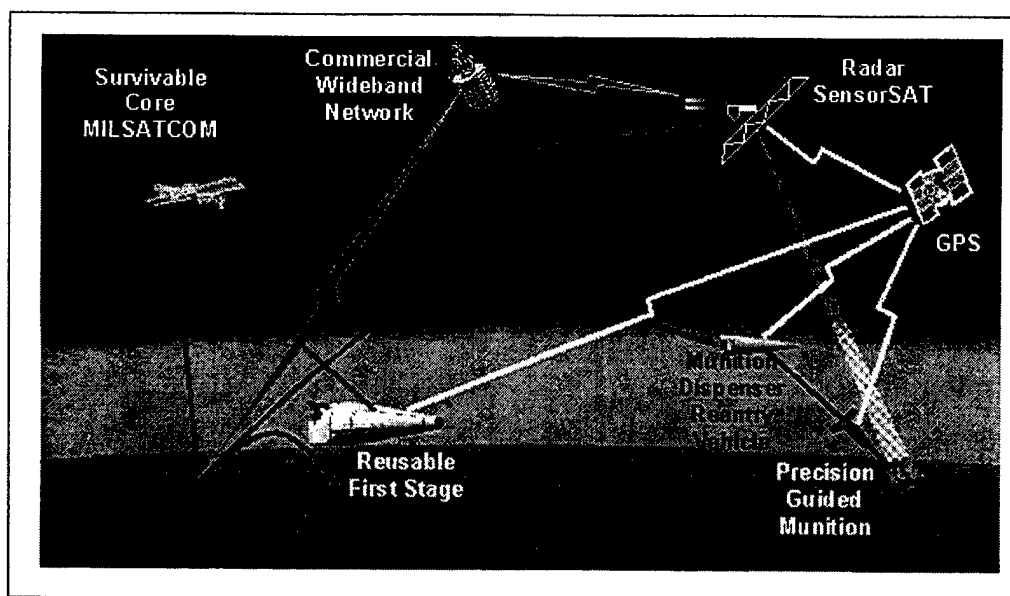


Figure ES-2. Rapid, Precise, Global Strike Capability Illustrates the Potential of Aerospace Forces to Contribute in New Ways to Achieving National Objectives

delivering precision-guided munitions at orbital speeds, combined with global, all-weather, synoptic, high-resolution sensing; precision navigation and timing; and responsive command and control. Such a system would permit destruction of the target in less than an hour from a National Command Authorities order with complete surprise, immunity to currently fielded active defenses, and a lower prospect of collateral damage. It could equally well conduct a photo reconnaissance mission to produce proof that a prohibited action was in progress. At the other end of the spectrum, Figure ES-3 (borrowed from the Information Management study that was done in parallel with this one⁶) suggests the pervasive role of aerospace forces in a major conflict, including the ability to facilitate cooperation of joint and coalition forces to deliver the maximum total military effect. Here, space systems create information-rich warfighters, negate asymmetric threats like theater missiles, and make the diverse elements of the force interoperable. These examples illustrate capabilities that have not been available in earlier conflicts and that have enormous potential to promote the nation's security and influence.

⁶ 1998 SAB Study on Information Management.

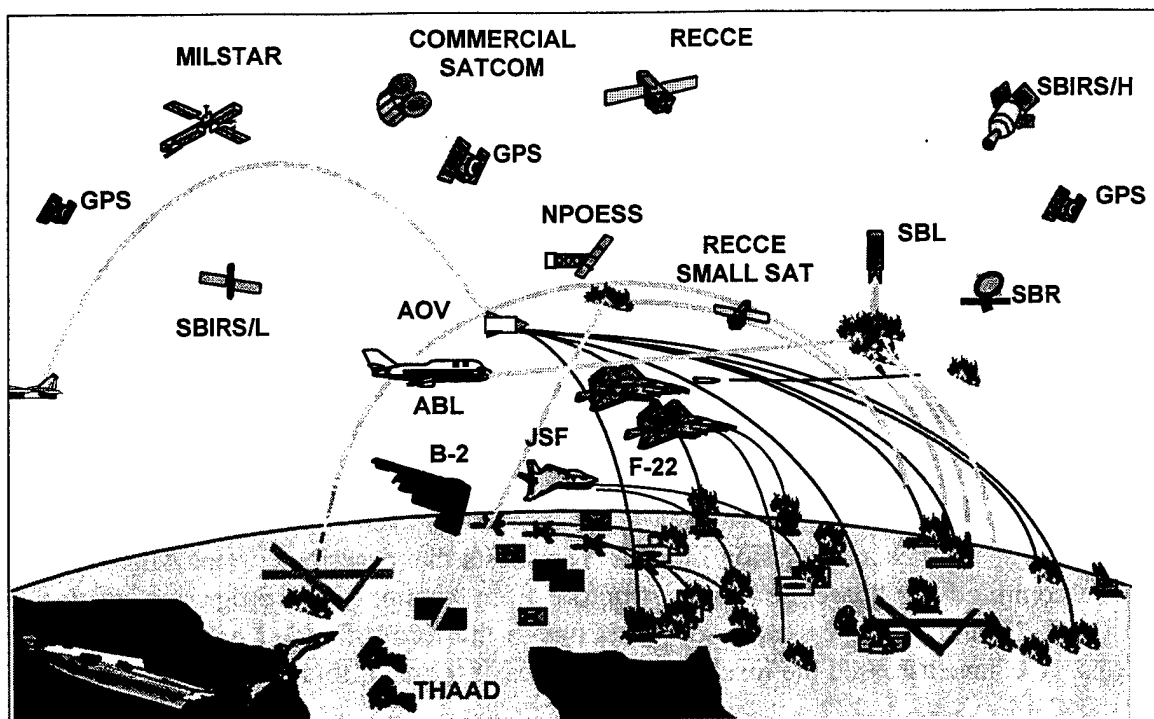


Figure ES-3. Integrated Aerospace Power Is an Essential Element of Joint and Coalition Warfare

PAYING FOR CHANGE

However, the other side of this coin is the reality of military budgets and end strengths that are inadequate to satisfy current needs, let alone pay for major new force structure initiatives. In order to fund new and modified systems, the Air Force will have to find ways to save money elsewhere. There are a number of such areas, and all of them involve hard choices. They include:

- Getting out of some mission areas, including things like space launch that have a long history as Air Force “stewardship” missions. The Air Force should limit itself to military-unique functions that fall within its core competencies.
- Dramatically changing requirements generation, acquisition, and operations to an approach in which buying commercial and applying commercial practices to how the Air Force does business are assumed to be the answer, unless it can be proved otherwise.
- Taking advantage of partnerships, synergism among systems, and carefully scrubbed requirements to pare acquisitions to the minimum that will accomplish the mission. This includes treating airborne and space systems involved in common functions like ISR as an integrated force structure that is optimized as a whole, and thus requires a true system-of-systems architect empowered to enforce such decisions.
- Doing large-scale streamlining of operations, again using commercial models, to eliminate thousands of personnel (whose positions can be used to fill other critical needs) and get rid of expensive and unsupportable facilities and equipment.

- Breaking the mindset that each program area in the Air Force budget has a “fair share” percentage which cannot be changed by other than trivial amounts. Total Obligation Authority (TOA) will probably have to be moved into the space area from other programs, at least in some years of high space activity. Failure to do so will send a clear message to DoD and the world that the Air Force is not serious about taking a leadership role and becoming the aerospace force that the nation needs. However, as discussed in more detail in the body of this report, the available offsets will help a great deal with this problem.

A VISION OF THE FUTURE FORCE

In this study, we have started with a vision of 21st century aerospace operations, drawn both from earlier analyses such as New World Vistas and Spacecast 2025 and from the Desired Operational Capabilities and Mission Element Task Lists that describe current Air Force tasking. We have compiled the “baseline” force structure from planning and programming documents (see Table 2-2), and we have evaluated excursions in the form of added or deleted systems and functions. We have assessed the resulting alternatives in terms of four measures of effectiveness:

- Operational Effectiveness—ability of the resulting force structure to address current and projected tasking
- Affordability—ability of the alternative to fit into an executable program within reasonable budget projections
- Technical Risk—availability of the required enabling technologies and products to implement the system or systems under consideration on a given schedule
- Integration—ability of the alternative under consideration to maintain continuity of service to warfighters and to fit into an evolving force structure, including backward compatibility as appropriate

A future aerospace force which can implement this vision, yet be feasible in the likely fiscal circumstances, will be characterized by:

- Effectiveness—in executing the exceptionally diverse taskings that will be laid on it
- Survivability—when exposed to new, ambiguous, asymmetric and rapidly changing threats
- Efficiency—in delivering precise effects with great economy of resources

From our analysis, we have arrived at a number of recommendations which are discussed in more detail in this volume and in the individual reports prepared by each of the panels composing the study team. They fall into three categories. Those which impact combat performance tend to support both effectiveness and survivability; those that deal with infrastructure have their primary payoff in improved efficiency. A third set are concerned with how the Air Force does business today and lays the groundwork for future progress. For each recommendation, we suggest one or more Offices of Primary and Collateral Responsibility

(OPRs/OCRs) to work the issues, and we give a reference to the section of the main body of this volume where a fuller description is to be found.

We have taken the Doable Space Quick-Look study⁷ as a point of departure, and have concentrated on the "equipping" dimension of evolving the aerospace force. Our study complements the work of the Aerospace Integration Task Force (AITF) and other related efforts. We rely on the AITF to develop the conceptual foundation for aerospace employment in the 21st century and to embody it in an Aerospace Integration Plan (AIP). The AIP will define new theory and doctrine for the future aerospace force and the strategies needed for equipping, resourcing, training, educating, and organizing for integrated application of air and space assets. Our results are also fully coordinated with the parallel SAB study on Information Management and support earlier studies on Unmanned Aerial Vehicles and Aerospace Expeditionary Forces. We have enjoyed extensive participation and support from the National Reconnaissance Office (NRO) and have assiduously sought information from the Army, Navy, Defense Advanced Research Projects Agency (DARPA), National Aeronautics and Space Administration (NASA), and industry. In short, while this is an independent report presenting the objective opinion of the study team, we have worked hard to ensure that all relevant facts, user requirements, joint and coalition warfare concerns, and related programs are properly considered.

PRIMARY RECOMMENDATIONS

Enhanced Effectiveness and Survivability

Move to a Network-Centric, Global Grid Information Architecture. The Air Force should plan and execute the earliest feasible phase-out of noncore military satellite communications (MILSATCOM) operations in favor of commercial services and interoperable user terminals (core MILSATCOM is that capacity which must have levels of assurance and security above what commercial service can provide, presumed to be provided by the Milstar system). Evaluate a maneuverable MILSATCOM system that can be positioned for optimum support to specific theaters as needed. In so doing, the Air Force should maintain backward compatibility to legacy user equipments for a reasonable period of time, but not indefinitely. The Air Force should develop with commercial satellite communications (SATCOM) providers a set of on-orbit gateways to provide robust access for military users. The Air Force should develop and install affordable aircraft SATCOM antennas to provide connectivity between aircraft and the information infrastructure. (See a later recommendation on partnering with industry.) Disparities in military and commercial communications coverage and bandwidth requirements must be resolved before placing primary reliance on commercial services. *Recommended OPR:* HQ USAF/SC. *Recommended OCRs:* SAF/AQ for acquisition, HQ USAF/XO for operational matters, and HQ USAF/XP for long-range planning. *Refer to Section 3.1.*

Develop and Deploy a Global, All-Condition, Intelligence/Surveillance/Reconnaissance Capability. The Air Force should continue current risk-reduction and concept definition efforts, as well as analysis of associated concepts of operations (CONOPS), to define the requirements for a space-based radar system, initially capable of synthetic-aperture radar imaging and ground

⁷ Doable Space Quick-Look, AF/ST, 1998.

moving-target indication. The new sensor constellation should complement NRO, civil, and commercial systems in providing the information for global situational awareness, with a target Initial Operational Capability date not later than 2010. The frequency allocation problem needs continuing attention, preferably in partnership with emerging commercial space radar systems for earth observation. *Recommended OPRs:* SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF/XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for initial planning and programming for a follow-on engineering development, manufacturing, and deployment program. *Refer to Section 3.2.*

Provide Robust Position, Navigation, and Timing (PNT). In keeping with national policy arising from the recommendations of the Global Positioning System (GPS) Independent Review Team and a proposed Presidential Directive, the Air Force should retain, on behalf of DoD, ownership and management of GPS. The Air Force should provide the advocacy needed to maintain adequate budget priority for purely military PNT functions, especially robust services to warfighters in hostile environments through system improvements and augmentation as recommended by the Joint Program Office. At the same time, the Air Force should continue to provide civil and commercial services, and should vigorously pursue GPS funding from other, especially civil, agencies. The Air Force should similarly develop and field capabilities to selectively deny these services to adversaries. *Recommended OPR:* SAF/AQ. *Recommended OCRs:* HQ USAF/XO for operational matters, and HQ USAF/XP for long-range planning. *Refer to Section 3.3.*

Prepare for Global Energy Projection. Do not proceed with large-scale, on-orbit high-energy laser demonstrations such as the proposed Space Based Laser Readiness Demonstrator at this time, but pursue aggressively the precursor efforts needed to enable global energy projection at the earliest feasible date. The Air Force should develop a CONOPS for the employment of high-energy laser projection from space, using space-based or terrestrial lasers, and should conduct requirements analysis to identify the most effective and affordable approach to implementing such a system with the capability to deliver tailored effects, both lethal and nonlethal. Alternatives to the usually assumed chemical lasers should be explored, including electrically powered solid-state lasers. No development or deployment decisions should be made until the military worth and optimum approach are established. The Air Force should start now a focused technology development effort in areas supporting high-performance optical systems in space, with emphasis on large, lightweight, low-cost optics. *Recommended OPRs:* SAF/AQ and HQ USAF/XO for current technology and CONOPS developments, respectively. *Recommended OCRs:* SAF/AQ and HQ USAF/XO for overall acquisition and operational matters concerned with each other's OPR responsibilities, and HQ USAF/XP for long-range planning. *Refer to Section 3.4.*

Improve Space Surveillance and Develop a Recognized Space Picture (RSP) Construct for the Common Operating Picture (COP). The Air Force should migrate selected space surveillance functions to space. A possible approach is to modify the Space-Based Infrared System (SBIRS) Low constellation to perform both its primary warning mission and tracking

of objects in high orbits.⁸ The Air Force should implement enhancements to ground sensors, especially a supportability upgrade to the FPS-85 Spacetrack radar,⁹ and should evaluate the value of importing and fusing data from Army missile defense radars. The Air Force should lead the development of an RSP corresponding to existing air, ground, and maritime pictures, under the COP. As a key element of the RSP, the Air Force should provide timely attack warning and reporting for all satellites used by the military. *Recommended OPR:* HQ USAF/XO. *Recommended OCR:* SAF/AQ. *Refer to Section 3.5.*

Protect U.S. Space Assets Against Likely Threats. The Air Force should take a number of steps, including encryption, selective hardening of satellites, use of system and orbital diversity/redundancy, threat location, and physical security for ground sites, to minimize the risk from the most likely future threats. The goal should be maximum mission survivability at minimum cost. *Recommended OPRs:* SAF/AQ for acquisition and HQ USAF/XO for operational matters, respectively. *Recommended OCR:* HQ USAF/XP for long-range planning. *Refer to Section 3.6.*

Develop a Space Test Activity and Adequate Modeling, Simulation, and Analysis Tools. It is urgent that the Air Force be better able to demonstrate the military worth of aerospace. The Air Force should ensure that emerging or updated models at the campaign and mission/engagement levels accurately portray the characteristics and effectiveness of air and space systems; one promising opportunity is the National Air and Space Model at the Electronic Systems Center. The resulting analytical capability should be used to support system requirements definition, operational analysis, integration of air and space, and many other purposes. The Air Force should create a space test activity, exploiting existing systems to keep costs low. This activity will be useful for development and operational testing, training, system effectiveness evaluation, and similar purposes analogous to those performed for aircraft by air test ranges, but allowing such activities to occur in the real space environment. *Recommended OPR:* HQ USAF/XO. *Recommended OCRs:* SAF/AQ for acquisition and HQ USAF/XP for long-range planning. *Refer to Section 3.7.*

Preserve the Option to Develop an Aerospace Operations Vehicle (AOV). The Air Force should continue the current Space Maneuvering Vehicle demonstration and perform analysis of associated CONOPS to develop a system concept and a plan and roadmap for a phased program with clear milestones for continued development in the event the results of these activities warrant a follow-on. A program decision should be made in approximately 2002. The Air Force should provide the minimum level of funding in the area of reusable launch vehicles (RLVs) needed to ensure that the NASA-led effort addresses Air Force lift requirements. *Recommended OPR:* SAF/AQ. *Recommended OCRs:* HQ USAF/XO for CONOPS analysis and system concept definition and HQ USAF/XP for long-range planning. *Refer to Section 3.8.*

Space Control. Classified aspects of the Space Control area are discussed in the Space Control Panel report.

⁸ *SAB Report on Space Surveillance, Asteroids and Comets, and Space Debris, Vol. 1: Space Surveillance*, SAB-TR-96-04, June 1997, pp. 11-15 and Appendix 1.

⁹ *Ibid.*

Enhanced Efficiency

Transition National Launch Facilities to Civilian Operations with the Air Force as a Tenant. The Air Force should act in two steps to exit the launch operations field except for essential military missions: Step 1—award an omnibus contract for operation of the Eastern and Western Ranges, with economic provisions for modernization of facilities. Step 2—transfer responsibility to a suitable civil agency (e.g., support creation of a National Space Port Authority) for operations and to the Federal Aviation Administration for safety. Continue direct cost commercial launch pricing for onshore launch through the national program. Provide up-front funding, if required, to make privatization feasible as a business opportunity. Phase-out legacy tracking systems in favor of GPS-derived tracking (a “space-based range”). *Recommended OPR:* SAF/AQ for transition policy. *Recommended OCRs:* HQ USAF/XO for operational matters and HQ USAF/SP for long-range planning. Transfer of responsibility involves multiple organizations and national policy. *Refer to Section 3.10.*

Transition Launch to Primary Reliance on Commercial Services. The Air Force should begin an orderly phase-out of most current organic booster procurement and launch programs and should increase use of commercial launch services, leading to primary reliance on them. Retain minimum essential organic launch capability, possibly in the form of the AOV, for payloads that cannot be commercially launched. The Evolved Expendable Launch Vehicle program should be completed, and the Air Force should maintain close coordination with NASA to support RLV technology. Satellite design, especially weight, should be predicated on compatibility with commercial launchers. *Recommended OPR:* SAF/AQ for transition policy. *Recommended OCR:* HQ USAF/XO for operational analysis and planning. *Refer to Section 3.11.*

Implement Commercial Models and Other Improvements to Satellite Operations and Tracking. The Air Force should streamline satellite operations by transitioning to a commercial model for staffing and system operation; outsourcing noncritical functions; separating payload control from tracking, telemetry, and control to allow optimization in each area; and making selective investments in ground equipment upgrades where justified by manpower savings and other benefits. The Air Force should make better use of Air Force Reserve personnel to raise skill levels and reduce training and turnover in satellite operations. For new systems, developers should be required to apply best commercial practices (e.g., spiral development) and to set and apply performance metrics for human factors. The Air Force should plan and execute an orderly phase-out of legacy tracking assets and replace them with GPS-derived tracking; commercial options for operation and upgrading of tracking systems should be considered. *Recommended OPR:* SAF/AQ. *Recommended OCR:* HQ USAF/XO for manpower and operations planning and reform. *Refer to Section 3.12.*

Enhanced Programs and Practices

Create an Air Staff Concept Development Process and Central Aerospace Architecture Function. The Air Force should create a central focus for dealing with issues associated with (1) an integrated aerospace system-of-systems architecture that balances space, air, and surface

capabilities; (2) conducting an ongoing, proactive partnering with the commercial space industry; and (3) aligning the requirements process and acquisition practices with the realities of a space environment that is dominated by commercial enterprises. This includes creation of a concept development process structured around a properly empowered force structure architect and requirements coordinator with the authority to perform trades among force structure segments and coordinate requirements to deliver maximum warfighting capability for the resources available. The aerospace architect is the logical authority to oversee the continuing interaction with industry. No new personnel are required to implement this function, but integration across multiple current Air Staff activities is essential. At the same time, the Air Force should reform the requirements definition process to focus only on key performance/capability parameters and to shorten the requirements approval cycle to be consistent with commercial product lifetimes (which are often 18 months or less). As part of this reform, requirements should be iterated with commercial capabilities to ensure that commercial space is properly accounted for and should replace traditional platform-centric thinking with a capability or mission focus based on employing the best available combination of systems and other assets. *Recommended OPR:* HQ USAF/XP. *Recommended OCRs:* HQ USAF/XO and SAF/AQ. *Refer to Section 5.1.*

Develop and Implement Aerospace Power Doctrine and Strategy. The Air Force should develop the doctrinal basis for integrated aerospace power and should carry it out through strategies that apply that power effectively to satisfy assigned tasks. *Recommended OPR:* HQ USAF/SP. *Recommended OCR:* Air Force Doctrinal Center. *Refer to Section 5.2.*

Improve Acquisition Practices. The Air Force should make both a *revolutionary* change to switch from military to civilian models for system development, procurement, and operations, and an *evolutionary* change based on continuous improvement throughout the program. Elements of this include:

Adopt a policy that the assumed approach to any procurement is to buy commercial, with alternatives such as government system developments requiring justification for an exception to this rule; maintain high-level emphasis to overcome resistance and inertia in the affected organizations.

Adopt commercial practices such as business case analysis, streamlined procurement, and spiral development of ground segments; develop an acquisition work force with the skills to effectively execute commercial procurements and cooperative endeavors. Use commercial space wisely to exploit its advantages while protecting military interests and meeting military-unique needs.

Require a comprehensive acquisition strategy as a fundamental part of a program plan from the outset, restore a high-level program review process analogous to the "summits" of prior years, and develop improved cost/performance models that improve visibility into program status and identify effective initiatives to deal with emerging problems.

Maintain adequate budget reserves in acquisition programs to minimize reprogramming actions and avoid highly visible program disruptions.

Require human factors practices and metrics in system development.

Recommended OPR: SAF/AQ. *Refer to Sections 5.1, 5.3, and 5.4.*

Focus the Technology Base on Military-Unique Technologies. The Air Force Research Laboratory (AFRL) has initiated action through the FY 00 Program Objective Memorandum to

significantly increase support to space and deserves credit for tackling this difficult but necessary reorientation of the Technology Base program. However, both this initiative and the overall health of the Technology Base are in jeopardy as a result of recent budget cuts. In keeping with the overall move to greater reliance on commercial space, AFRL should structure its program on the basis of (a) funding military-unique technology needs not likely to be met by commercial sources, (b) funding competing concepts to those in commercial development, (c) identifying and pursuing opportunities to insert technologies in both commercial and military applications, and (d) maintaining longer-term high-risk/high-payoff technologies where commercial companies cannot justify investing. In addition, AFRL should focus on the areas identified in this study where critical technology needs exist, e.g., for low-cost, lightweight space optics and reusable launch vehicles. Senior Air Force leadership should strongly support AFRL with Office of the Secretary of Defense and the Congress in obtaining approval of the necessary changes. Recommended OPR: SAF/AQ. Recommended OCR: AFRL/CC. Refer to Section 5.5.

Develop and Execute a Coordinated Program for the Integrated Aerospace Force. The Air Force should pursue a coordinated set of programming and budgeting actions to achieve the integrated aerospace force. Building on and continuing the work of the AITF, an executable program should be constructed through TOA adjustments and through economies and transfers of responsibility that help offset resource increases. A preliminary and high-level budget analysis done as part of this study suggests that a large part of the resources required can be made available from within the current baseline space superiority program area, minimizing the requirement to transfer funds from other program areas. A more detailed budget and program analysis is required to quantify costs and economies and develop a coherent programming strategy, including the possibility of transfers of TOA among program areas. Recommended OPR: HQ USAF/XP. Recommended OCRs: HQ USAF/XO and SAF/AQ. Refer to Chapters 4 and 6.

SUMMARY

In order to meet the obligations likely to be laid on it in the years ahead, the Air Force must complete the transition to a flexible, responsive, integrated aerospace force that is organized, trained, and equipped for a broader range of missions and tasks than ever before. In so doing, it must place unprecedented emphasis on affordability and on shedding activities that do not properly belong in the Air Force program. Commercial space and partnerships with other Government agencies offer important opportunities which must be sought out and pursued. Technology breakthroughs increasingly allow us to deploy markedly improved systems while reducing development and operation costs. However, none of this will happen without new approaches and the leadership to put them into action.

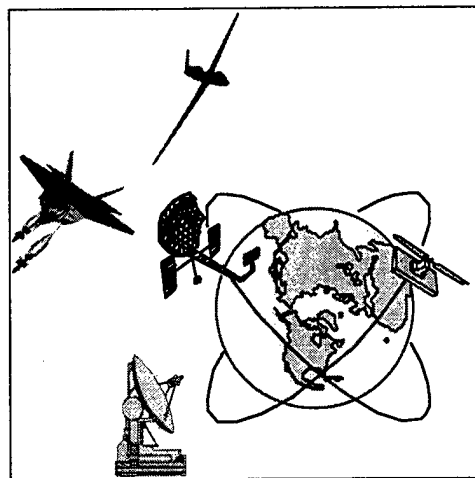
Effecting this transition in an era of flat or declining budgets will be brutally hard, and some cherished Air Force traditions and politically powerful vested interests will suffer in the process. The Air Force faces huge budget problems in space (and almost everywhere else) whether this study's recommendations are acted on or not. There is no way out of this dilemma that does not involve both changing fiscal priorities and divesting large pieces of today's Air Force mission and infrastructure. As one example, thousands of military manpower authorizations that are now

dedicated to support activities in space system and launch operations can be replaced with a far smaller workforce, largely contracted out, and moved to fill urgent needs elsewhere. This would be consistent with the development of a corps of aerospace warfighters, skilled in all the dimensions of applying spaceborne and airborne instruments of national power.

We are convinced that the Air Force can and must make the necessary changes within the constraints of budgets and system development timelines. Actions should begin immediately to streamline organizations and operations, to make better use of commercial opportunities, and to better incorporate space capabilities into terrestrial operations. For example, procurement of space and airborne ISR systems should be based on an integrated functionality and should account for the contribution of commercial and other Government systems. The result will be to buy fewer platforms and to avoid wasteful overspecification of any single element in the total force structure. The work of the AITF is especially important here.

Inescapably, to reach the levels of capability which we believe will be increasingly necessary, money will have to be spent on several carefully defined new systems and on upgrades to a number of legacy systems. Restructuring of the budget must start during the current Future Years Defense Program (FYDP), and we project significant investment needs to arise toward the end of the FYDP period. These largely can be offset by savings in many areas. Planning and programming preparations should start immediately, along with decisions on organizational restructuring, outsourcing and privatization, transfers of missions and facilities to other agencies, and other economy measures.

We have tried in this study to outline the kinds of actions the Air Force must take and to establish the basis for a concrete and detailed program roadmap which should now be developed through the program planning and budgeting process. We understand the difficulty of the course we advocate. However, the alternative is for the Air Force to become progressively less capable of doing the jobs that will be assigned and less relevant as an instrument of national power. The time to make the commitment and take the first steps is now.



CHAPTER 8.

***Concepts and Technologies for the Army Beyond 2010,
Army Science Board***

CHAPTER 8.

Concepts and Technologies for the Army After 2010 (AA2010), Army Science Board

INTRODUCTION

During November 1997, the Army Science Board (ASB) initiated a study dealing with Concepts and Technologies for the Future Army (Circa 2010) referred to as the Army After 2010 (AA2010), interchangeably also called the Army After Next (AAN). Substantial effort was already underway to modernize the near term Army (Army XXI) by leveraging information technology.

The activities of the Study consisted of monthly two-day plenary meetings starting in November 1997 and ending in July 1998, along with one or two-day meetings each month by various Panels. The Panels addressed a variety of topics – air lift, sea lift, containerization and modularity, weapon platforms and systems, lethality, C⁴ISR and situation awareness systems (SAS) capabilities, joint force support, training and education, dismounted combat and modernization strategy. Experts drawn from Government, academe and industry assisted the Panels.

The study was completed with an Executive Briefing and Report Writing Session at the Beckman Center on the campus of the University of California in Irvine. This effort produced this Executive Summary and an Executive Summary Briefing consisting of 51 viewgraphs. Its Background and Context are treated in a short six chart section. The majority of the assessment is contained in the sections labeled a) Mobility and Sustainment, b) Information Dominance, c) Platforms and Weapons and d) Investment Strategy and Recommendations.

TERMS OF REFERENCE

A Terms of Reference (TOR) for this ASB study was prepared and staffed in the early fall of 1997. It was finalized at the time of the November meeting of the ASB Study Group. During the first Plenary Meeting, a video teleconference was employed to bring the Study Group and its Sponsors together. The TOR directs the Study Group to review Joint, Army and other Service Concepts and give emphasis to Joint missions involving land combat. It is for these that technologies and enablers were sought. In the same context, the Army's modernization and technology planning was assessed.

BACKGROUND AND CONTEXT

With regard to concepts and missions for the future, the largest Joint missions involve generating, projecting, protecting and sustaining the Joint forces. Unlike combat operations where there are clearly defined responsibilities and unity of command, these larger Joint

activities are spatially, command and means segmented. They are multi-Service, employ commercial capabilities and are supported by host nation means in-theater.

THREATS AND CONCEPTS

Substantial effort has been made to estimate circumstances that would represent future challenges to US national security. Such effort provides a consensus that future threats will be different from those of the past. They will also encompass a greater spectrum of threats and will require a broader range of U.S. capabilities.

In the past, preparations were made to produce threat offsets in the competition with the Soviet Union. Marginal superiority was sought in areas understood to be critical. Forward basing, theater prepositioning and reinforcement provided hedges. All other threat circumstances were judged to be lesser included cases and required little or no special treatment.

Possibly the most insightful characterization of the future threats has been to establish the idea that there is no single overriding and central threat. Preparing for one, assuming all others to be included cases, is a poor starting point. In addition, attention has been justifiably given to asymmetric threats.

In this period of both uncertainty and preparedness, the JCS and Services have embarked on future force planning. Joint Vision 2010 (JV2010) is the overlying vision for the future. It posits dominance in all phases of future operations, particularly in the critical domains of power projection, sustainment, force protection, engagement and maneuver. These built on a base of high quality leaders and soldiers and superb training, should both enhance deterrence and produce much more continuously favorable engagement and ultimately campaign circumstances than in the past.

The Services have embraced this vision in their “flagship” efforts such as AA2010 (AAN). Shaping subordinate processes and programs is now underway. Thus, the Army’s (and other Services) research, development and acquisition leaders as well as those which support joint activities (such as TRANSCOM) have engaged in the search for means and technologies to underwrite the six central capabilities which comprise JV2010.

The Army is now, as it has always been, an Army in transition. The current Army of Excellence (AOE) is being modernized by exploiting information technology. An example of this is the “Applique Internet” and its follow-on “Tactical Internet.” Over the next ten years, the Army will modernize its units with information systems that will reduce, but not totally eliminate, today’s stovepipe systems. It will as well provide battlefield information to platforms and dismounted soldier teams which should enable unprecedented situation awareness. Exploiting these circumstances will require substantial advances in training, in various simulation domains and education, particularly distance learning in units.

AOE transitions to Army XXI through information exploitation, the addition of new platforms and systems, and improvements to existing – sometimes called legacy – platforms, weapons and systems. In a parallel effort described correctly as a campaign, AA2010 comes into being with successive generations of “Battle Forces” – experimental, developmental and fielded.

Battle Forces are mechanized/motorized units which are rapidly strategically deployed by air. Their platforms – primary and supporting – are also moved operationally and tactically by air when desired or feasible. Ground mobility will be improved with respect to current platforms and forces. Sustainment and endurance improvements sought are an order of magnitude greater than achievable today. The traditional terms – light, heavy – are blurred and probably not relevant to the Battle Forces. Improvements which are needed to realize desired Battle Force performance levels will in many cases provide great benefits to Army XXI.

It is not possible to exactly quantify performance improvements at this time. However, it is possible to estimate what makes a difference. Today, a well prepositioned Brigade can be manned, generated and in position in five days. A Battle Force unit projected from the CONUS might accomplish the same in two days or possibly less. Thus, the Battle Force design goals are best described as improvements of factors of 2 to 3 or more over current forces in each of the domains of deployability, survivability, lethality, sustainability and operational-tactical mobility. Taken in combination, along with drastically reduced manpower and equipment in-theater footprints, appropriate combinations of AA2010 Battle Forces and Army XXI elements could provide the equivalent of an AOE Corps combat capability – air deployable worldwide – sustained by air until the arrival of prepositioned and sealift-deployed follow-on forces within two weeks or less.

MOBILITY AND SUSTAINMENT

Unit lift requirements are described for two purposes (chart 10 from the Executive Summary Briefing). The first is comparative relative to available military air lift fleet capabilities. The second has to do with continuing sustainment. A regional CINC has very difficult choices to make in setting priorities for rapid air lift DoD assets. Deploying an F-16 air wing and a protecting Patriot battalion exceeds today's one-time air lift capabilities. Future weight reductions will improve these specific circumstances but will not change the fundamentals.


Battle Force elements and units must be made as robust and as light as possible for similar reasons. Sustainment by air runs afoul of the same limitations. Volume considerations are equally important. These limitations could reduce deployable combat power before weight limits are reached.

All the Services – Army, Marines and Air Force – which require airlift for rapid power projection have heavy and bulky equipment and have substantial resupply requirements. The Army's 70 ton tanks (used also by the Marines) are the "bumper sticker" perception example of the heavy force but the facts are otherwise.

TRANSCOM's future strategic fleet structure will be 246 aircraft including 120 C-17s (which are really optimized for intra-theater purpose with much shorter takeoff and landing circumstances). Cargo throughput capability is approximately 50 million ton miles per day, including the Civil Reserve Air Fleet (CRAF). It is important to note today that CRAF represents a substantial portion of the required strategic airlift capability.

In the future, CRAF could be the dominant lift component, providing the Army with a non-organic air lift fleet of traditional and non-traditional CRAF platforms. This will save the DoD

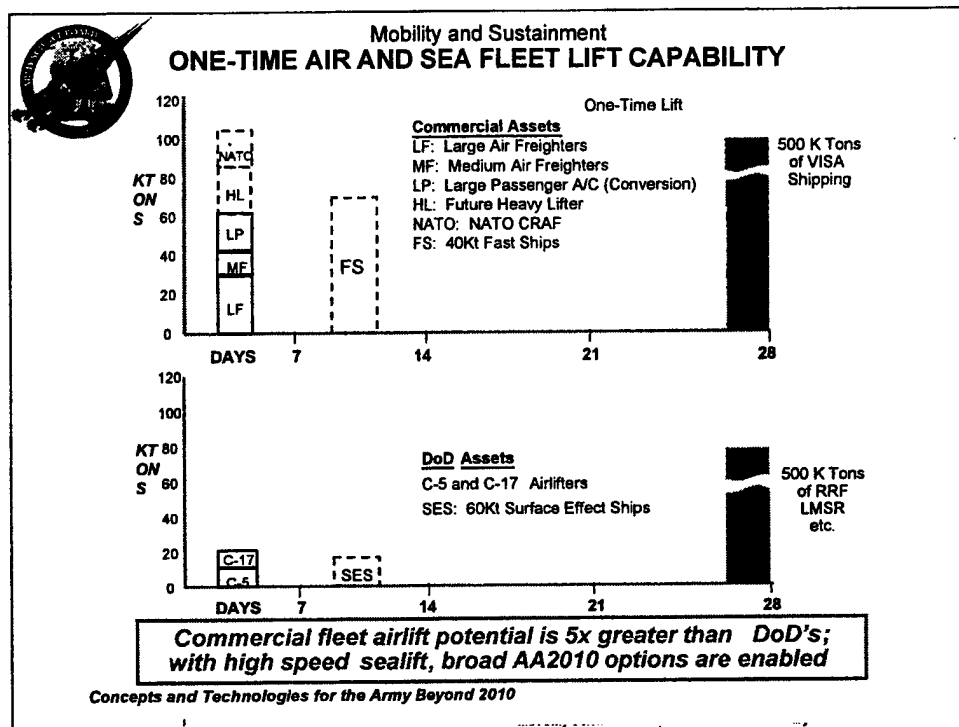
the expense of expanding its strategic lift fleet and allows the C-17 to be freed for intra-theater lift to augment the C-130 fleet. This dramatically expands theater capabilities because of the 80 ton C-17 payload and its shorter landing and takeoff requirements. The following chart addresses this possibility and addresses sea lift as well.

 Mobility and Sustainment UNIT LIFT REQUIREMENTS				
UNIT	MANNING	PRIMARY PLATFORMS	TONNAGE OF OVERALL UNIT	DAILY FUEL & AMMO TONNAGE
Air Wing	5000	72	7000	1300
AEF Air Wing (estimate)	2500	72	4000	1300
Patriot BN	651	81	15000	100
AOE MLRS BN	132	27	2400	260
AOE ARTY BN	663	24	3300	220
MAGTF (estimate)	2711	150	15000	600
AOE BDE	5000	400	25000	800
AAN Battle Force (estimate)	6000	1400	13000	300
DoD C-5 and C-17 fleet have - 4,000 NM unrefueled lift capacity - 17,000 ton one-time lift INSUFFICIENT FOR ANY POSTULATED JOINT EARLY ENTRY FORCE DEPLOYMENT				
Concepts and Technologies for the Army Beyond 2010				

It is worth noting that TRANSCOM's future planning shows no growth in CRAF capabilities. This is indeed strange because projections by several sources show commercial fleet growth rates of 7% per year. Explorations of this disconnect suggest that TRANSCOM has received no requirement for additional CRAF support.

An analytic construct of one-time fleet lift potential (in kilotons); as shown in the following chart, is used to portray the relative contributions of various elements of a future mix of strategic lift means. For illustrative purposes, a deployable range of 8000 nautical miles is assumed. It shows that commercial assets, conservatively estimated, dominate DoD assets (chart 12).

TRANSCOM air deployment potential using C-5 and C-17 aircraft is slightly less than 20,000 tons delivered in 2-3 days at 8000 nautical miles. A small DoD fleet of 60 knot, 2000 tons payload surface effect ships could deliver the same tonnage in 8-12 days (cost = \$4-5B). Commercial airlift is projected to this time frame at growth rates of 7%. Assuming CRAF III and 50% U.S. ownership of the worldwide fleet, it is seen that an assumed commercial capability substantially exceeds that of DoD. In addition to U.S. traditional commercial CRAF assets, there are additive possibilities with a NATO CRAF initiative and the stimulation and adaptation of commercial heavy airlifters such as a proposed commercial aerolifter and a future blended wing body. Rapid sea lift provided by 40 knot commercial ships and 60-knot surface effect ships will provide quick follow-up to forces initially deployed by air.



The Army should modify its Army XXI equipment where feasible and affordable and design its improvements and the Battle Forces to meet the door and floor loading constraints of traditional CRAF. These are now becoming known in the Army requirements and development community. The Army should also be a pro-active CRAF supporter and expand these fleets by changing policies, practices and marketing approaches.

Proper exploitation and stimulation could provide circumstances for air insertion of Battle Forces in one to two days and Army XXI brigades in ten to twelve days by seas. Stimulation and adaptation of a commercial aerolifter class platform could provide airfield and port free operations with the incorporation of defense features such as VTOL or a hover-winning capability.

Battle Forces are currently envisioned as having 3-D mobility (near vertical air insertion and extraction of the Battle Force from unprepared sites). The largest load could be a 15-ton combat vehicle. Airlift missions might be flown to operationally significant distances (up to 1,000 km radius) by rotorcraft or more traditional aircraft.

A RAND study to evaluate the dual use potential of a National Transport Rotorcraft concluded that there was only a niche market for large (8 ton payload) rotorcraft. The result is that DoD investment will be required to create a large (15 ton payload) V/STOL transport.

2-D and 2-1/2-D mobility implies drive-in/drive-out and fly-in/drive-out respectively. Various forms of airdrop, including low-altitude parachute extraction, could be used for 2-1/2-D insertion. This would allow the use of conventional military airlift assets such as the C-17 instead of development of a new military V/STOL transport.

There are three general cases which must be considered in assessing needs for operational-tactical lift which would underwrite full 3-D, 2-1/2-D and 2-D mobility. These are: a) administrative entry, b) disrupted entry and c) opposed entry. Strategic lift by military or CRAF means apply to all cases. The circumstances for operational-tactical lift and AA2010 vary substantially. Understanding the tradeoffs and the most robust solutions deserve a substantial inquiry well beyond the ASB's resources. The AA2010 analysis to date falls short of a development and acquisition case.

Lift alone does not assure rapid deployment. The entire non-unified DoD process must be optimized. The commercial world has moved beyond DoD in total transportation systems and processes. The FedEx X-Box air/land container system is an excellent example. It fits into the current air/land transportation system; it is light enough for efficient air transport; and it includes a modular X-Pad that can be moved by forklift. This is just part of the total system including asset tracking, automated cargo handling and ground crew training.

DoD should consider taking advantage of the entire system. This means requiring that new military equipment be designed to take advantage of the commercial transportation system. It should be containerized and modular, as appropriate. It must fit into commercial airfreight aircraft. And, it must be compatible with commercial asset tracking and automated handling systems.

The commercial transportation system integrates processes facilities equipment and trained people. DoD should consider encouraging CRAF operators to employ members of the Reserves, who could be called up as a unit, together with their air and ground equipment.

In the design of the Battle Forces, the Army should plan to employ both DoD and commercial lift means as well as commercial processes to include modularization and containerization. Experts and expertise from the commercial sectors should be part of the AA2010 design effort.

INFORMATION DOMINANCE

Information dominance has been identified as a crucial integrating and enabling capability for the Battle Force. Many technologies that can contribute to gaining information dominance have been identified by the study panel and those deemed most critical are enumerated in the following paragraphs.

Battlefield visualization provides operational context for evaluation, interpretation and swift decision making. The lack of archived terrain data and the inability to rapidly collect terrain data has inhibited current situational awareness systems and developing battlefield visualization capabilities. The Battle Force must have ready access to a rich terrain data set that is updated to meeting changing mission needs.

Battle Forces will be able to utilize the synthetic environments with terrain data in support monitoring of battle, course of action (COA) development and analysis, and mission rehearsal. DARPA's Discover II program offers major contributions with its MTI and SAR capabilities. Tasking and reporting in real and near real time at the battalion level must be maintained as features. Its DTED 5 performance is critical for mapping.

Hyperspectral imagery will be very important to provide fine ground terrain and featured interpretation. These inputs will be further exploited in operational assessment (e.g., mobility, Course of Action, etc.)

To accommodate faster OPTEMPO by the Battle Force, the timelines for the military decision making process and for engagements will be compressed. C⁴ISR systems for situational awareness and sensor-to-shooter links must likewise accommodate these compressed timelines. Although embedded C⁴ISR systems will have the primary purpose of supporting warfighting, soldiers of the Battle Force must also be able to use them to support learning, experimentation, planning and training. This will require new functionality to be added to the C⁴ISR systems.

The OPTEMPO of the Battle Force will demand that command and control (C²) activities is done while traveling in ground vehicles or aircraft. As contrasted with the past, the Army must focus advances and modernization at the battalion level. This constitutes a true challenge for C⁴ISR systems that must be enhanced to support C² on-the-move. The Battle Force will fight along side Army units using legacy C⁴ISR systems and Joint and combined forces. The C⁴ISR systems used by the Battle Force must be interoperable with those systems used by others. Communications for the Battle Force must be assured. Leveraging satellite and fiber optic services and technologies must be part of the solution because this sector outspends the DoD by a factor of 30 or more and modernizes three to four times faster.

The ASB conducted a 1997 summer study on "Battlefield Visualization." That study concluded that warfighter understanding of a battle's progress and alternative courses of action are enhanced by using computer graphic renderings of battle activities. Recommendations from that study are re-emphasized here, as they are important for Battle Force situational awareness. Terrain data at DTED level 5 is crucial for computer graphic renderings of the battle but the Army does not now have adequate archives nor the ability to rapidly obtain the necessary data.

Commercial communications could and should play an important role. In the area of terrestrial fiber, there are several companies (such as Qwest, AT&T, Sprint, MCI Worldcom, etc.) that are laying large capacity fiber backbones in CONUS. The GTE Qwest backbone, for example, spans 92 metropolitan areas and has a capacity of almost 5 terabits/sec. (Assuming the size of this briefing is 2MB, this is enough capacity to send almost 2.5M copies across the CONUS in one second).

In global fiber telecommunications, the situation is similar. Many companies (such as AT&T, Global Crossing, Ltd., etc.) are laying transoceanic fiber. Transatlantic traffic is growing at a rate of 80% per year, and all bulk capacity is sold out for the foreseeable future. Fiber technology is robust in growth potential, as the theoretical bandwidth limits are extremely high (on the order of 100 terabits/sec per dark fiber strand); with the current limitations being the switching speeds. Continents such as Africa and South America are being ringed with fiber.

The global telecommunications market also includes satellite telecommunications. Most market projections predict that global satellite telecommunications will grow extremely rapidly, enough to capture at least 10% of the total global telecommunications market. Although satellites have some disadvantages they are extremely attractive in the "last mile" applications, which are likely to be of high importance to AA2010 operations. Despite being limited in overall capacity (in the 10s of gigabits/second in aggregate bandwidth) and older technology (due to the 5-10 year

lag in launch times), they allow point-to-point communications without the need to lay fiber or “dig ditches.” Hence, the projected growth.

Market forecasts in these business areas show no sign of slowing investment in the foreseeable future. It is the ASB’s judgement that commercial communications should be the preferred means between higher (Brigade and above) echelons and should be a redundant capability for Battalion operations.

Current and possibly future links (terrestrial and space-based) are individually vulnerable to a modest variety of weaknesses and exploitation modes. The Army working with DoD should provide partnering which eliminates these and results in a robust network of networks.

DARPA has several ongoing command and control programs – Command Post of the Future for higher command echelons and Small Unit Operations (SUO) Situation Awareness System (SUO-SAS) for battalion through team operations. It is contemplating a mobile tactical operations center (TOC) for high OPTEMPO continuous battalion and brigade operations. This development would pursue the capabilities needed for Command and Control on the Move (C2OTM) with innovations such as stabilized displays.

All three developments are important to the Army and should be fully exploited by the Army with senior attention program management and future funding.

The Battle Force design architecture is one that is intended to produce highly integrated overall force and platform capabilities, which have strong interdependencies. Capabilities for engagement and protection are dependent upon information dominance and the ability to reach out and lethally engage before being engaged.

There is good news relative to CTC-like training, distance learning (DL), mission rehearsal and After Action Reviews (AARs). This set of methodologies, processes and capabilities set the Army apart from all other armies in the world. The current digitization program with a mode expansion provides all of these for circumstances as different as asynchronous Distance Learning to instrumented force training at home stations.

Bringing together concepts, organization and technologies for robust C⁴ISR in the battalion environment is a formidable challenge. However the Army has had a similar but smaller challenge with digitization.

It should expand the multimode man- and hardware-in-the-loop CECOM simulation and evaluation used so successfully for both definition and design of digitization’s hardware and software and then ported into SIMNET to provide a learning, training and experimentation basis for the troops. Expansion of this “test bed” and adoption of DDRE’s Sensor Web concepts (for sensor systems and networks) will provide the Army the means to achieve C⁴ISR and SAS performance needed for Battle Force operations.

PLATFORMS AND WEAPONS

The effectiveness of the contemplated AA2010 Battle Force will be strongly dependent on a number of interlinking factors, including the overall force composition (platforms, weapons, personnel); the availability of current situation awareness information; the capabilities and

reliability of local and wide area communications links; the ability to generate timely, accurate, and high lethal firepower at extended ranges; supporting Joint fires; individual platform and overall force survivability; and the ability to execute sustained operations for several days without external ammunition resupply or vehicle refueling. The force concept is based on the ability to execute fast-paced, sustained operations using a fleet of lightweight, highly mobile and agile ground vehicles, supported by VTOL attack aircraft and robotic ground and air platforms.

The survivability of these platforms, particularly ground systems, poses a significant challenge, particularly in urban environments. Achieving individual platform survivability will require the effective integration of a number of vehicle design features and critical subsystems, including active protection system (APS), capabilities against highly lethal KE and CE threats, signature management (RF and IR), and advanced EW and other defensive countermeasure systems.

Overall force survivability will be enhanced through the combined synergistic benefits of cooperative engagement and long-range fires, including the timely delivery of munitions from loitering platforms. Dominant force lethality will be realized via a weapons mix that includes high-performance KE and CE munitions, in conjunction with new directed energy systems (HPM and lasers).

Missiles and precision guided mortar/smart munitions (PGMs) technologies will continue to advance in every area, particularly in the seeker and propulsion areas. PGMs with lock-on-after-launch (LOAL) capability should be available for imaging infrared, ladar and dual mode/multi-sensor type seekers – essentially automatic target recognition (ATR) capability for narrow fields of view.

The exploitation of controllable thrust propulsion technology provides an opportunity for mission tailoring the thrust profile for a wide variety of target situations with a potentially large increase in effective range. For example, missiles in the 100 pound range may have effective ranges from 1-200 km against a wide variety of targets and with the option for loitering and cooperative engagements.

Similar improvements in warheads and guidance and control (G&C) are expected. G&C options should include “aim-point-selection” (for maximum lethality), mission tailorable trajectories and data links for man-in-the-loop (MITL) and “sensor to munitions” updates to target intercept while the munitions are in flight.

There are two potential breakthrough areas. I²R Focal Plane Arrays have become significantly more capable over the last two decades. The number of individual pixels in modern missile/munitions seekers are at least 64 times larger than seekers in development in the early 1980s. Comparable improvements in ladar and millimeter wave seekers can be expected. Integrated multi-spectral sensors/processing technologies like acoustics or special signal processing should be an option for this time frame. The need for increased range and precision “beyond-line-of-sight” engagement will demand many of these advanced technologies and capabilities.

The AA2010 force will have a robust array of offensive and defensive options, each contributing to overall force lethality and survivability. The insertion of robotic vehicles, both ground and air versions, will provide an unprecedented ability to see, track and attack the enemy

with high precision and at significant stand-off ranges. Unmanned ground vehicles and unattended sensors will provide an ability to exploit advanced, long range precision guided munitions throughout the battlespace. Robotics will also benefit AXXI to the same degree.

Unmanned air vehicles will complement these reconnaissance, surveillance and target acquisition (RSTA) capabilities to include rapid, dynamic battle damage assessment (BDA). In the 2015-2020 time frame, cooperative engagement capabilities should be available to allow near real-time sensor-to-munitions links with in-flight updates to target intercept until seeker/sensor lock-on or impact. Long range weapons (~200 km) in the 100 pounds weight class should be available to include loitering capability for 5 to 20 minutes and provide rapid engagements time lines (seconds versus minutes of latency). The combination of these unmanned systems and smart/brilliant munitions should provide the force major advantages in survivability and dramatically reduce manned system losses.

Future advanced/active protection systems (APS) can provide a very robust capability to defeat most precision or ballistic threats to smaller and less detectable vehicles. Active countermeasures suites will provide broad spectrum protection. However, other force level technologies/capabilities (such as situation awareness and information operations) will significantly enhance unit/force survivability.

The Army is investigating a comprehensive array of very capable PGM technologies. These PGM capabilities will be a key factor in designing future forces that are easier to deploy and sustain, have overmatching lethality and range to provide flexibility in both OPTEMPO and agility. The challenge is to determine the best balance or blend of technologies given substantially reduced resources and the high R&D cost of getting PGM programs into production. The DARPA Advanced Fire Support System (AFSS), commonly referred to as "munitions-in-a-box," may provide exciting new opportunities for PGMs for many different types of missions. The concept may provide a valuable opportunity for developing a consolidation or neck-down strategy for AA2010 PGMs. Given expected resource constraints, only a few different PGMs types would seem to be reasonable. The process to determine (through analysis and experimentation) which ones are best for this application may be helpful in defining the consolidation process.

The DARPA AFSS program includes consideration of a new missile, one that could have both multi-role capabilities and be designed for conventional platforms. If the missile exploits variable thrust propulsion and optional wing-type lift technology, engagement capabilities beyond 200 km could be realized. An overall consolidation strategy should also consider selected upgrade of other high value PGMs to provide the AA2010 force a wide range of lethality options. A holistic approach to force lethality is needed to promote overall efficiency and warfighting capability.

The Army has launched a Future Scout and Cavalry system program. This will be closely followed by a Strike Force vehicle family initiative which is a precursor for Battle Force platform developments. It is recommended that SARDA employ these programs as "testbeds" in the broad sense for components and sub-systems which are critical for the future. Some may require emulation. Others may have live but not fully mature representations.

Candidates include hybrid electric drive (which might also be a precursor for full cell employment) applied to manned and unmanned platforms as well as for signature management. The Army must make some major innovations in platform crew size, tasking and the use of robotics to achieve the air-mech capabilities desired. Commercial industry could and should supply the hybrid electric capability and technology and save substantial time and money for the Army.

Similarly, currently planned improvement programs (Crusader, MLRS, etc.) should be considered as vehicles to examine improvements that could provide major advantages to Army XXI and Critical Technologies for conceptual Battle Forces. These initiatives would include redirecting EM launcher work to providing medium caliber and artillery capabilities, extended range and loitering rounds as well as technical needs to support cooperative engagement to reduce or eliminate latency. In the course of exploiting electric launchers, the Army should consider initiatives which could enhance the realization of non-traditional laser and high powered microwave devices.

Dramatic improvements and unparalleled flexibility would attend the successful upgrading of both Crusader and its rounds. Crusader has the power and volume to employ near-term electromagnetic launch components that are volume and energy/power diversity limited (the reason for the concerns about EM possibilities are main tank armament). With these and a flexible sabot-rail combination, it could launch payloads ranging from 50 kg (approximately the weight of the current 155 mm round) to 500 kg at the same muzzle energy of 10 MJ. The rounds heavier than 50 kg would be non-ballistic and fly to and loiter at their targets.

Such improvements would provide major enhancements (3x to 5x) for the overall Joint force in terms of combat effectiveness (measured in tons of lethality delivered to the enemy) per ton of sustainment relative to today's means.

The Army's program to enhance the capability for dismounted combat operations are also critical for the current and future force. The major technical challenge has been, is and will always be the weight carried by the infantrymen. Today, the technology-dominated approach has not met this challenge.

The ASB suggests two possible directions for a broader solution to this problem. The first is in the organizational and operational (O&O) concept. It should be broadened from soldier as a system to soldier team as a system because soldiers train and operate in teams not as individuals. This is not just an editorial nuance and it goes to the heart of solving the weight problem. As an example, the team members could each carry an element of a team corporate radio which as a corporate radio has the required maximum performance. Each soldier would carry his smaller, lighter part of the corporate radio that would have adequate but limited performance characteristics.

Similarly, the teams should have a vehicle to carry the major (and heavy) elements of the team's kit. The vehicle could also provide the recharging capability for the many batteries needed. The team vehicle will probably be paid for many times over just in the savings from batteries.

INVESTMENT STRATEGY

The current (FY 98) Army Modernization Plan addresses improvements in terms of the Investment Categories and Patterns of Operation for the near, mid and far term. At best, such a methodology would account for contributions of an initiative (e.g. M1A2 upgrades, Crusader development, Land Warrior, etc.) to Patterns of Operation or to tradeoffs among them. The surface interpretation (which the documentation creates) suggests it is a sorting with loose holistic ties to Patterns of Operations or implied force capabilities. The Plan, while very informative, does not provide a sense of absolute or relative priorities or the sense of overall integration so critical to Army operations. It is similar to such plans for air and naval forces which are platform based and whose entity scale is hundreds to thousands smaller than those of the Army.

The Investment Strategy does not reflect possible contributions from commercial and non-Army government programs, means, processes and technologies. It does not reflect the significance of projecting the force, as an example, and tradeoffs that relate to this crucial force capability. It does not reflect the inherent tradeoffs between information dominance and protecting the force that is important to Army XXI but is at the core of the design of AA2010.

The Science and Technology priorities for AA2010 show these same fundamental shortfalls. In the case of AA2010, positive interdependencies are at the heart of achieving the desired force capabilities. In the case of both the investment and S&T strategies, the Army is being limited by its bottom-up and stovepipe mechanisms. Integration is the key to the future. It must be part of the Strategy for Investment.

Central Recommendation

The first and central recommendation put forward in this report identifies a series of on-going commercial and non-Army DoD developments whose exploitation could materially benefit the Army. An investment Council is recommended as a means to select and focus attention on all or a subset deemed to be most adaptable and affordable. An example of the issues that might be addressed are shown in the chart below. This approach would also provide a means to communicate to at least the Army, OSD and the Congress its priorities and its ability to leverage developments outside the Army. While it could be described as "Opm", using other people's money, it is substantially broader and more sophisticated than this simple description implies.



Recommendation

SCIENCE AND TECHNOLOGY INVESTMENT STRATEGY EXAMPLES

Gain early access to participate in and influence programs which could affordably underwrite substantial capability improvements in AOE, Army XXI and AA2010 through

- Major **COMMERCIAL** investments being made in
 - Expanding air transport (passenger and freight)
 - Providing innovative heavy and outsize cargo air lift
 - Providing innovative fast sea lift
 - Establishing seamless, synchronized, high throughput intermodal means and processes
 - Transitioning automotive propulsion to hybrid electric power
 - Providing a capability explosion in worldwide access and high bandwidth fiber and space-based communication networks
 - Providing expanded space surveillance and mapping
- Major **GOVERNMENT, NON-ARMY** investments to demonstrate
 - Near-staring space-based MTI - SAR Tactical RSTA (DARPA + NRO + AF)
 - Survivable C2 on-the-move (DARPA)
 - Organic, high resolution battalion SAS (DARPA + DDRE)
 - A near-revolutionary C-130 replacement (AF+ industry)
 - JSTARS

Concepts and Technologies for the Army Beyond 2010

As an example, the Army could employ as a sophisticated multifaceted adoption of both traditional and innovative forms of air lift and sea lift and the employment of Reserve Component forces to generate, receive and sustain the forces and project power rapidly and affordably and in the most modern forms possible. In doing so, it is partnering with and leveraging the continuing strength and world class performance of the US economy. The benefits internal to the Army include bringing order and focus to the random and lesser-used process of building on commercial strengths, investments and modernization rate. Similarly, the Army can derive economies of scale from non-Army DoD developments.

RELATED RECOMMENDATIONS

High level interactions are needed between senior Army leaders and senior leaders from the industry. The purpose is threefold:

1. Understand where both traditional and innovative capability growth is going and gain a seat at the table in continuing discussions.
2. Formulate and execute programs within the Army to adopt, support and encourage favorable developments (not necessarily limited to technologies but including means, integrated capabilities and processes).
3. Understanding and acting on additional possibilities in these sectors particularly, on one hand, where Allies and friendly nations could be beneficially involved and, on the other, where US government action and influence can be brought to bear in addition to funding.

DERIVATIVE RECOMMENDATIONS

1. Within the Army, CG TRADOC and CG FORSCOM, assisted by CG AMC, should undertake a program to make a substantial improvement in modularity and containerization in all its forms to achieve higher throughput, confident logistic support and reduced choke points and concentration which might attract enemy measures with unconventional and conventional weapons and weapons of mass destruction – nuclear, biological and chemical.
2. The Army should formulate its expanded CRAF, Visa and APOE/APOD needs to meet CINC requirements and JV2010 needs for the future. It should engage OSD, JCS, TRANSCOM and DLA in these developments.
3. The Army should employ the digitization capabilities to support CTC-like home station training, distance learning, mission planning and rehearsal and after action reviews.
4. The Army should, in conjunction with OSD, undertake a program to leverage commercial communications in survivable and enduring networks and at the same time exploit commercial and non-U.S. space surveillance capabilities.
5. The Army should employ the Future Scout and Cavalry System and the Strike Force initiative as test beds to bring along important technological innovations such as:
 - Hybrid electric drive
 - Directed energy and high power microwave weapons
 - Advanced active defenses
 - DARPA “rockets in a box” program
 - Signature management
 - Robotic vehicles
 - Modularity and containerization for all phases of deployment and sustainment.
6. The Army should change the organizational and operational (O&O) concept for the soldier as a system (land warrior) to the soldier team as a system and alter priorities and RDA accordingly.
7. The Army should prototype and experiment with individually and in combination.
 - An EM version of Crusader (as a P³I initiative) with a multicaliber launch capability
 - Loitering rounds for a variety of purposes
 - Close combat
 - “Rockets in a box”
 - Long range “artillery”
 - Cooperative engagement execution

CHAPTER 9.

***Technology for the United States Navy and Marine Corps,
2000-2035: Becoming a 21st Century Force, Naval Studies
Board, National Research Council***

CHAPTER 9.

Technology for the United States Navy and Marine Corps, 2000-2035: Becoming a 21st Century Force, Naval Studies Board, National Research Council

INTRODUCTION

This appendix is a summary of the nine volume study accomplished by the Naval Studies Board (NSB), with emphasis on the technologies the NSB identified that the Defense Science Board (DSB) studied. The purpose of this appendix is two-fold:

- Provide a broad overview of the nine volume NSB report.
- Identify common threads between the NSB and DSB.

TERMS OF REFERENCE

The NSB terms of reference were to identify present and emerging technologies that relate to the full breadth of Navy and Marine Corps mission capabilities. Specific attention was directed to reviewing and projecting developments and needs related to the following: (1) information warfare, electronic warfare, and the use of surveillance assets; (2) mine warfare and submarine warfare; (3) Navy and Marine Corps weaponry in the context of effectiveness on target; (4) issues in caring for and maximizing effectiveness of Navy and Marine Corps human resources. Specific attention was directed, but not confined to, the following issues:

1. Recognizing the need to obtain maximum leverage from Navy and Marine Corps capital assets within existing and planned budgets, with emphasis on surveying present and emerging technical opportunities to advance Navy and Marine Corps capabilities within these constraints. The review was to include key military and civilian technologies that can affect Navy and Marine Corps future operations. The technical assessment was to evaluate which science and technology research should be maintained in naval research laboratories as core requirements versus what research the commercial industry could be relied upon to develop.
2. Information warfare, electronic warfare and the exploitation of surveillance assets, both through military and commercial developments, were to receive special attention in the review. The efforts were to concentrate on information warfare, especially defensive measures that affordably provide the best capability.
3. The review was to recognize the serious threats to future naval missions posed by mine warfare and submarine warfare. The NSB was to investigate both new considerations such as increased emphasis on shallow water operations, and current and future problems resident in projected worldwide undersea capability.

4. Technologies that may advance cruise and tactical ballistic missile defensive and offensive capabilities beyond current system approaches were to be examined. Special attention was to be given to counters to conventional, bacteriological, chemical and nuclear warheads.
5. The full range of Navy and Marine Corps weaponry was to be reviewed in the light of new technologies in order to generate new and improved capabilities (for example, improved targeting and target recognition.)
6. Navy and Marine Corps platforms, including propulsion systems, were to be evaluated for suitability to future missions and operating environments.
7. Application of new technologies to the Navy's medical and health care delivery systems were to be assessed, realizing that in the future Navy and Marine Corps personnel may be called upon to serve in non-traditional environments, and face new types of threats.
8. Efficient and effective use of personnel were identified as being of critical importance. The impact of new technologies on personnel issues, such as education and training, recruitment, retention and motivation, and the efficient marriage of personnel and machines was to be addressed in the review.
9. The study was to evaluate how technology could be used to enhance Quality of Life (QOL) and define militarily meaningful measures of effectiveness (for example, the impact on Navy readiness). Housing, barracks, MWR facilities, commissaries, child care, etc. were all recognized as part of the QOL of naval personnel.
10. The study was to review the overall architecture of models and simulation in the DoD (DoN, JCS, and OSD), the ability of the models to represent real world situations, and their merits as tools upon which to make technical and force composition decisions.

Tab 1 is a listing of all nine volumes of the NSB study. It includes a synopsis of subjects covered in each volume. Tab 2 is a summation of the recommendations found in each volume.

FUTURE ENVIRONMENT

In regards to the future environment, the study states that the future environment in which the naval forces will play a key part is likely to change much more rapidly than the naval forces themselves can be changed. A great deal of adaptability must therefore be incorporated into them from the start. The identity of the issues shaping the future environment are similar to current reports such as the joint strategic review (JSR) and the national defense panel (NDP). Highlighting the list of issues is the reduction in overseas bases, the realization that joint and coalition operations are likely to become the norm, and the proliferation of technological capabilities that make it difficult for the U.S. to maintain its traditional lead. This last point is especially true regarding information technology and space based observation.

Several issues will present difficulties to expeditionary operations. Anti-ship cruise missiles not only continue to threaten expeditionary operations, but the widespread availability of these missiles magnifies their threat. Similarly, the availability of increasingly accurate, low cost

guidance systems for ballistic missiles are also an increasing challenge to expeditionary operations. Quiet, modern submarines and torpedoes will cruise the coastal regions we will operate from, mines are becoming increasingly difficult to detect and eliminate in the littorals from the deep water region continuing through the shallow water and ashore. Anti-aircraft weapons and systems are becoming more effective and nuclear, chemical, and biological weapons continue to be a concern.

NSB: Future Environment*

- ★ **Fewer U.S. overseas bases**
- ★ **Joint & coalition operations the norm**
- ★ **Proliferation of technology & capabilities —hard to maintain U.S. lead :**
 - ★ *Space observation*
 - ★ *Information warfare*
- ★ **High risk to expeditionary operations**
 - ★ *Anti-ship cruise missiles*
 - ★ *Accurately guided ballistic missiles*
 - ★ *Quiet modern submarines & torpedoes*
 - ★ *Mine warfare*
 - ★ *Effective anti-aircraft weapons & systems*
 - ★ *Nuclear, chemical, biological weapons*



**Similar to DSB High End Environment*

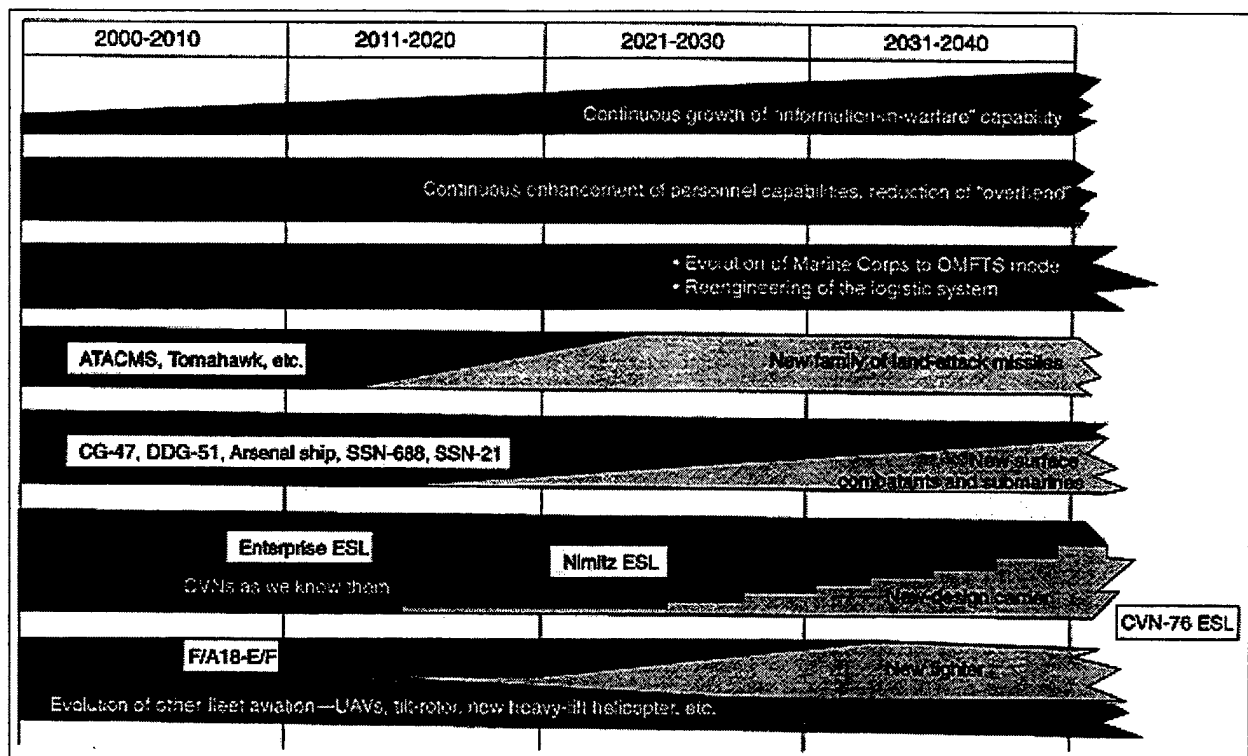
The tasks that naval forces are required to perform have changed little over the decades and are expected to continue in the future. They will include:

- Sustaining a forward presence;
- Establishing and maintaining blockades;
- Deterring and defeating attacks on the United States, our allies, and friendly nations, and, in particular, sustaining a sea-based nuclear deterrent force;
- Projecting national military power through modern expeditionary warfare, including attacking land targets from the sea, landing forces ashore and providing fire and logistic support for them, and engaging in sustained combat when necessary;
- Ensuring global freedom of the seas, airspace, and space; and
- Operating in joint and combined settings in all these missions.

Many explorations of new technical and operational directions are under way in the naval forces—in approaches to using information in warfare, in the emerging Marine Corps Operational Maneuver From the Sea doctrine and concepts of operation, in personnel management, in ships, aircraft, submarines, weapons, and their employment and logistic support,

and in joint operations and usage. These new directions, which imply radical change in the future naval forces, have already begun to create the entering wedges of capability upon which future naval forces will be built. The emerging capabilities must be tested operationally in the forces and their ultimate development guided in directions that will ensure their viability. When these directions are determined, the new capabilities must then be joined with existing long-term investments in C⁴ISR systems, weapon systems, and platforms that will remain useful in any kind of naval force for years and decades to come, in an evolutionary approach to restructured naval forces.

One such evolutionary approach is depicted in the illustration below. The figure shows the decades between 2000 and 2040 during which many existing weapon systems and platforms will reach the end of their service life (ESL), and during which replacements embodying the new capabilities could enter the forces. The implementation schedule shown is not a "hard and fast" recommendation, but illustrative. It recognizes that some investments, such as those in major ships like aircraft carriers and a generation of combat aircraft, have very long service lives, and that weapon systems, like the family of attack ballistic missiles described previously, will take time to develop with all the technical characteristics that advance them significantly beyond today's weapon systems.



NSB FINDINGS

The areas listed here are not all inclusive of the NSB study, rather items that are common to areas the DSB studied.

SURFACE SHIP AND SUBMARINE DESIGN

All future ship and submarine designs will be able to take advantage of fully integrated, distributed sensors, actuators, and automation to minimize crew size and maximize system performance with the smaller crews. It will be possible to retrofit existing ships and submarines with these capabilities as well. A significant start has been made in this direction by the Navy's "smart ship" demonstration. In future ship and submarine designs, and in planning retrofits to the extent feasible, the crew, the logistic support, and integrated damage control will all have to be considered parts of the system from the start, and the entire system designed as a whole.

Additional design features made possible by advancing technology will include:

- Passive signature reduction and capability for signature management in all regimes, for enhanced stealth and survivability;
- Integrated electric power systems and advanced electric drive for more efficient and effective arrangement and use of ship volume;
- Surface ship structures made of composite materials, for reduced signature and maintenance;
- Advanced hull forms to enhance speed, seakeeping, and stealth for surface combatants; and
- Open architectures with modular design to enable more rapid and less expensive maintenance and upgrading of weapon and other ship and submarine systems.

Future tactical submarines will embody much advanced technology, especially in sensors, stealth, power density, and efficiencies attending the development of electric drive and continuing research in nuclear plant design. They will have multimission capability oriented toward support of expeditionary naval force operations. This will include the ability to launch and recover auxiliary vehicles. The submarines will be able to fire large numbers of land-attack missiles from appropriately designed vertical launch systems, and they will need the ability to communicate with the combat information system to enable them to carry out sustained attack missions against targets on land when hostile detection and land-based defenses pose unacceptable risks to the surface fleet or its missions.

INFORMATION IN WARFARE

Information superiority must be established as a warfare area under an integrated organizational structure with responsibility for resource planning, program development, and budgeting for all Navy and Marine Corps information systems and services that are not unique to individual platforms or weapons systems. An information-in-warfare system for achieving information superiority comprises:

- Information sources, communications systems, information processing and fusion systems, and decision support and display systems, all seamlessly integrated by an infrastructure;

- The means for protecting these information systems and services by making them diverse, secure, and robust to attack or countermeasures; and
- The means to deny hostile forces the ability to degrade, disrupt, and/or utilize these information systems.

Today these three components are pursued separately and with unequal emphasis. The Department of the Navy must establish an organizational structure that integrates the development, protection, and denial of information services across all naval platforms in a "system of systems" context. The importance of maintaining a tight coupling between information sources, systems, and services to include intelligence, sensors, MCG (mapping, charting, geodesy), command and control, weapons, and targeting systems cannot be overemphasized. We are rapidly moving into an information-rich era involving highly mobile forces, precision-guided weapons, exquisite global situation awareness, focused logistics, and full-dimensional protection of our forces. Information superiority must be the centerpiece for any vision of joint and coalition force operations in the 21st century. Information superiority will not, however, be viewed with the importance it demands unless naval officers are rewarded, career paths established, and education programs put in place within this warfare area.

NSB: Sustained Information Superiority

★ Technology:

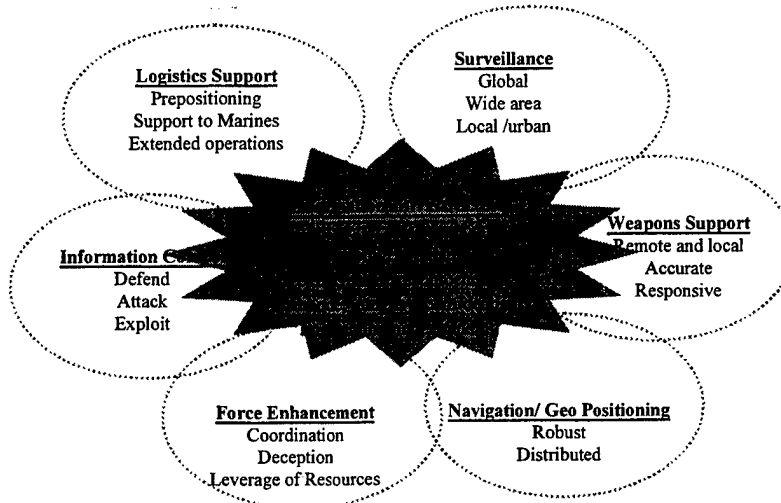
- ★ *Advanced space systems—navigation, communication, surveillance, environmental observation*
- ★ *Vast commercial infrastructure—space & terrestrial fiber*
- ★ *Information acquisition & manipulation technologies*
- ★ *Information warfare—offense & defense*
 - ★ *Offensive "cyber-warfare"—a new kind of conflict*
 - ★ *While surveillance, counter-surveillance & EW continue & improve*

★ Operational significance:

- ★ *Naval forces will have to adapt to the commercial infrastructure*
- ★ *Information superiority, an integrated warfare area*
 - ★ *Requires professional corps of people*
- ★ *Information understanding, the most critical problem*

DSB: Communications, ISR, and Information Control.₁₂

NSB: The Role of Information In Warfare



DSB: Communications, ISR, and Information Control

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FAMILY OF LAND-ATTACK MISSILES

Based on the high responsiveness, rate of fire, and precision of rocket-propelled guided missiles, it is projected that achievable future advances in the missile technology and reduction of their costs will make it possible to greatly enhance the suitability and utility of such missiles for ship- and submarine-launched attack systems. A family of such missiles of different sizes (5-in., 10-in., and 21-in. diameters) for strike, interdiction, and fire support will give the fleet greatly enhanced firepower and surge capability, allowing effective engagement of large numbers of targets of many kinds at various ranges in very short times. With appropriate guidance the missiles could also be used against seaborne targets, and the smaller missiles in the family could be adapted to air launch.

The proliferation of such attack missiles will affect the design of surface ships and submarines, and it will influence how combat aviation is used by the fleet. Because it can have such far-reaching effects, phased introduction of this capability is visualized. The missiles would be developed and used from available and currently planned launch tubes in the early phase. Commitment to major system, doctrine, and force structure changes would follow as the technology (including the anticipated cost reduction) proves itself and the forces gain confidence that the anticipated benefits will be realized.

The Navy's "arsenal ship" initiates and exemplifies the concept of a ship powerfully armed with missiles of the kind described, and others, to be available for the fleet to engage opposing forces pinpointed by the naval forces' joint targeting system. Studies of the tradeoffs between efficiency and effectiveness, on the one hand, and the vulnerability of a large increment of

military power embodied in one or a few ships, on the other, are needed to guide decisions about optimal numbers of such ships and of missile launch tubes on each such ship. After experience is gained with such ships, detailed studies of the comparative economics and effectiveness of aircraft- and gun-based systems and the missile-based systems, including consideration of all platforms and weapons in realistic scenarios involving the land, sea, and air forces, will be needed to design the mix of such systems in the overall forces.

NSB: Land Attack Guided Missiles from the Sea

★ Technology:

- ★ *Family of missiles (5", 10", 21")*
- ★ *Integrated precision targeting system*
- ★ *Ranges from 100-600 km*
- ★ *High accuracy*
- ★ *Improved destructive capacity*
- ★ *Lower cost*
- ★ *High VLS packing density at low launcher cost*

★ Operational significance:

- ★ *Greatly enhances fleet firepower & flexibility*
- ★ *Can also provide significant firepower for a small force*

DSB: Seamless Force Employment Force Protection

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FLEET AVIATION

Piloted aircraft for attack will continue to be needed in situations requiring the pilot's adaptiveness on the spot, visual target identification, delivery of larger warheads than the land-attack missiles will be able to carry, and sustained campaigns where the prospect of aircraft losses remains low. Defensive counter-air will be able to take advantage of networked, multistatic targeting techniques, enabling longer-range engagements with air-to-air missiles and surface-to-air missiles in the "forward pass" mode and alleviating the predicament, which is expected to persist, that foreign short-range air-to-air missiles will closely match those of the United States in performance. Aircraft providing close air support will add locally to the high volume of surface-launched fire support to help sustain the rapid pace of future ground operations.

New aircraft engine, structures, and flight-control technologies are expected to reduce the weight penalty for the short or vertical takeoff and vertical landing capability of fixed-wing aircraft. Thus, special emphasis on short takeoff and landing (STOL) or short takeoff and vertical

landing (STOVL) aircraft capable of flexible operation from a variety of ships and land bases is warranted for the next generation of fixed-wing naval force combat aircraft.

Preservation and enhancement of stealth in aircraft design will continue to be essential. Greater attention will be needed to reducing infrared signatures of aircraft to mitigate the threat of shoulder-fired, infrared (IR)-guided surface-to-air missiles (SAMs) at low altitude and of IR-guided air-to-air missiles in air combat, and there will be technologies to help in this area; the problem will intensify as staring IR arrays are introduced into the weapons. Advanced aerodynamics, microsensor activated controls, and materials permitting higher aircraft engine operating temperatures will offer the opportunity to expand the aircraft flight envelope, while new design and manufacturing technologies are expected to reduce production costs significantly.

There will also be a mix of unmanned aerial vehicles (UAVs) in fleet aviation. At one end of the mix will be high-altitude, long-endurance craft that may operate from carriers or be refueled from them in the air to provide the equivalent of a surveillance satellite in stationary orbit over naval forces at sea. At the other end of the mix, UAVs flown and recovered from carrier decks will be used for targeting opposing ground force elements and for other combat-related applications.

Aerial elements of amphibious operations, including attack helicopters, may be launched from large-deck carriers as well as from amphibious ships. Finally, the carriers will continue to operate ASW airplanes and helicopters, and other aircraft involved in surveillance and logistic support.

Carriers will thus become increasingly versatile as multipurpose air bases at sea. Carrier design can be expected to evolve in diverse ways with the need to operate all the existing and new kinds of naval force aircraft. All of the technology advances in crew reduction, signature management, and lightweight superstructures that will shape the next generation of surface combatants will be applicable to and beneficial for carriers.

MINE WARFARE

The Panel on Undersea Warfare chose to utilize the classified Naval Studies Board report *Mine Countermeasures Technology* as starting point for its examination of mine warfare technology. The panel also took account of the 1995 White Paper issued by the Chief of Naval Operations calling for a major sea change in the Navy's approach to MCM operations. Specifically, Admiral Boorda directed that the Navy's MCM force be transformed from a dedicated on-call force to an organic force capable of traveling at battle group speeds, and that MCM be mainstreamed into the fleet as a professional competency at all ranks and rates.

The panel's deliberations were guided by a view of MCM capability that enables effective pursuit of the following three objectives: (1) reduce the mine threat to its absolute minimum at each phase of an operation; (2) obtain maximum leverage of all available MCM assets; and (3) reduce the size and weight of all MCM systems without sacrificing capability. The panel believes that these objectives can be achieved and that a balanced MCM force, organic to the fleet and capable of removing the mine threat in keeping with an assault timetable or power projection

schedule, can be achieved at relatively modest cost by the year 2005. Further, the panel has identified technologies whose far-term development would provide the Navy and Marine Corps team with an effective MCM capability well into the mid-21st century.

Five main thrust areas must be pursued in order to meet the Mine Counter Measures challenge of the future:

1. Robust intelligence, surveillance, and reconnaissance capability.
2. Integration of MCM as a capability organic to the battle force. This includes specific MCM capability resident on selected battle group combatants and expanded MCM capabilities provided by MCM ships and helicopters that are transported with the battle group or the amphibious ready group (ARG).
3. Technologies that address primarily the very hostile mine detection and neutralization environment of the surf zone and the craft landing zone. These generally fall into the brute force category.
4. Advanced networked sensor and weapon systems consisting of controllable mines and including autonomous and semiautonomous detection devices.
5. Application of cost-effective mine shock hardening and acoustic and magnetic signature reduction technologies in all new construction ships.

On the path to the MCM capabilities of 2035, the panel believes that the near-term concepts, technologies, and systems should, when integrated with existing capability, provide the Navy-Marine Corps team with the ability to clear mines in stride by the year 2005 or earlier, at reasonable cost. The panel kept several objectives in mind when evaluating these concepts and technologies. The first objective is to pare the mine threat in a given campaign to the minimum that must be dealt with effectively as a function of three phases of the campaign-the most critical phase in which the first forces are inserted, the second phase when the heavy manpower and logistics must be landed, and the third phase when maximum sea-based traffic is expected. From the MCM standpoint, the major distinction between the phases involves the channel widths to be cleared and the time to do so. The second objective is to achieve a balanced and flexible MCM system capable of countering the full spectrum of mine threats. The third and final objective is to select concepts that will add clearance speed and efficiency to the MCM system at minimal costs and that can be implemented in the near-term future.

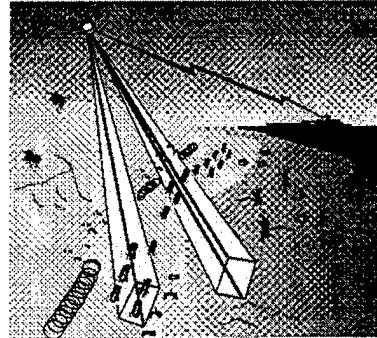
NSB: Minefield Neutralization

★ Technology:

- ★ Intelligence, surveillance, reconnaissance—know where the mines are!
- ★ SWATH craft ≤ 30 tons for hunting, neutralization, sweeping
- ★ Expendable mine neutralization vehicle, usable by air & surface platforms
- ★ Modern version of Navy's 1960s "CATSKILL" concept: specially outfitted LSD-41-type ship, deployable with ARG
- ★ Explosive excavation to create channels
- ★ Night operating capability for surface & air MCM forces
- ★ Upgraded tactical decision aids
- ★ Future possibilities:
 - ★ "Parallel" approaches
 - ★ High acoustic pulse power

★ Operational significance:

- ★ Negation of minefields within expeditionary operation timelines—achievable by 2005



DSB: Seamless Force Employment

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GROUND FORCE OPERATIONS IN POPULATED AREAS

Two aspects of such operations especially merit top-level attention:

- Making certain that there is adequate and accurate intelligence preparation to enter unfamiliar foreign areas where the local leaders and tactics could surprise and defeat U.S. forces. This will require some "educated guesses" about where such areas might be, as well as years of advanced preparation of plans and reading-in of potential commanders, along with the willingness to have some of that effort wasted because the need to use it may not arise.
- Extending the techniques and the intelligence preparation to terrorism and other nonconventional means of warfare.

LOGISTICS

Key areas for attention and application of modern technology include:

- Providing for distributed, computer-assisted readiness support, moving many support functions from sea to shore in the continental United States (CONUS) or a few forward bases, and taking steps to reduce personnel and use them more efficiently in shore installations and operations, just as is planned for shipboard;
- Ensuring total asset visibility from source to user, to reduce waste through excessive supplies in the system and to speed delivery of supplies;

- Building the system around containerized supply delivery compatible with commercial intermodal transport systems;
- Improving the capability for ship-to-shore transport, especially for movement over the beach, and for "retail delivery" to users beyond the beach; and
- Ensuring compatibility with civilian systems, since they may be called on to help when military capacity runs short.

Munitions constitute a large fraction (on the order of 40 percent) of the wartime logistic load. Shifting much of the strike and fire support from unguided bombs and shells to more frequent use of guided weaponry, and from air-launched to tube-launched weapons, is expected to significantly reduce the time required to defeat large target complexes and is therefore likely to affect ammunition resupply requirements for ships at sea and forces ashore in currently unpredictable ways.

UNDERSEA WARFARE

NSB: Submarines

★ **Technology:**

★ *Submarine platform design improvements*

★ *Included in combat suite:*

- ★ *Covert information gathering & IW capability*
- ★ *Family of land attack missiles*
- ★ *Launch & control of UUVs, control of UAVs*
- ★ *Launch & recovery of larger SOF operations*
- ★ *Adequate, secure communications*

★ **Operational significance:**

★ *Much greater submarine capability to support forces ashore*

★ *Stealthy forward combat force when or where risk to surface fleet is unacceptable*

**DSB: Seamless Force Employment
Force Protection**

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At some point, in less time than it will take the United States to catch up again, hostile submarines in this environment could be in a position to seriously inhibit operational maneuvers from the sea. Attention and funding to a level sufficient for the following tasks will have the greatest payoff for ASW:

- Extending the opportunities for passive detection, by taking advantage of advances in microsensors and fiber optics for very large sensor arrays and advanced computing to perform coherent signal processing;
- Applying the array signal processing mathematics and computing developed thereby to multistatic, active detection and tracking;
- Pursuing multispectrum active and passive nonacoustic sensors in parallel with acoustic sensor development;
- Netting all the fixed, surface, air, and submarine ASW assets in a cooperative engagement mode, and providing the essential tactical communications with submarines, both underwater and on the surface; and
- Improving antisubmarine weapons and counterweapons, with special attention to advanced warheads and performance in adverse littoral environments against sophisticated countermeasures and tactics.

Even with the increasing attention being given to countermine warfare by the naval forces, rapid minefield clearance to protect shipping areas and to facilitate over-the-shore naval force operations remains a difficult problem. Still needed are better means to rapidly focus countermine operations, and means for rapid minefield clearance, especially in the surf and craft landing zones. The former can best be accomplished by attention to intelligence, surveillance, and reconnaissance that will allow mine interdiction, minefield avoidance, and concentration of mine countermeasures (MCM) assets only where mines exist. The Global Positioning System (GPS) aboard all MCM and transiting ships and craft will permit significantly narrower cleared channels. Many small (e.g., 30 tons or less) sea and air MCM platforms supported by a suitable amphibious-type "mother ship."

MODELING AND SIMULATION

- The Department of the Navy must take a new look at modeling and simulation (M&S).
 - The very nature of warfare is changing, perhaps drastically. The U.S. style of war is becoming technologically complex and dependent on distributed and interconnected systems. Modeling and simulation will be core tools for planning and conducting warfare as revolutionary changes in military affairs take place, especially since intuition based on past wars will become less helpful over time.
 - *Independent of Navy and Marine actions*, M&S will be deeply embedded within joint command-and-control systems. Without enhanced efforts, the Navy and Marine Corps will not understand the strengths or limits of such models and simulations, nor be proficient with them.
 - M&S will also become a core feature of system development and acquisition, as is the case already in leading-edge civilian industry. Because of its centrality, M&S should be seen as an enterprise technology in itself-part of the revolution in

business affairs that is now a key element of the Department of Defense's DOD's overall strategy.

All of this suggests that the Department of the Navy needs to make an attitude shift regarding M&S, which has never previously merited a high priority for leadership attention. Today, what is needed is a strategic commitment to exploiting M&S.

The entire study is available on the internet at: <http://www2.nas.edu/nsb2/tfnf.htm>

SUMMARY OF RECOMMENDATIONS FROM VOLUMES 1 THROUGH 9 OF THE 1997 NSB STUDY

VOLUME 1: OVERVIEW

1. Plan and implement an aggressive program to create the entering wedges of capability that will position the naval forces to meet the challenges of the 21st century. Key technical capabilities anticipated by this study include:
 - Information superiority as an integrated warfare area; capitalizing on and adapting to the vast commercial infrastructure;
 - Technological support for highly qualified, better trained, and better educated people, retained in the force longer;
 - A family of rocket-propelled, surface- and submarine-launched, land-attack guided missiles (adaptable to air delivery and to other missions);
 - In combat aircraft: STOL, STOVL, standoff, and stealth;
 - Air-to-air cooperative engagement at long-engagement ranges;
 - Stealth and automation in ships, which must be designed as complete systems;
 - Unmanned aerial and underwater vehicles providing essential capabilities for combat;
 - Greatly expanded capability of submarines to support forces ashore;
 - Advancing ASW through coherent signal processing and cooperative engagement in undersea warfare;
 - Becoming able to clear mines rapidly during expeditionary operations;
 - Ability of small units to neutralize large, built-up, populated areas with minimal casualties and collateral damage;
 - A logistic system based on the use of modern information technology with lift, ships, and processes tailored for supporting forces at sea and ashore from the sea;
 - Modeling and simulation applied to acquisition, readiness, deterrence, and warfare: theory and methods to suit the needs of future naval forces for deterrence and warfare.

VOLUME 2: TECHNOLOGY

1. Information technology will dominate future warfare and must be elevated in priority. Rapid access to appropriate knowledge at all levels will optimize warfighting and crisis response capabilities. Commercial technologies in knowledge extraction, data management, and data presentation, together with unique military technologies in data fusion and automatic target recognition to deal with the increased complexity and tempo of warfare must be pursued. The Department of the Navy should develop offensive information and electronic warfare technologies to find, identify, and attack adversary systems and to strengthen naval systems.
2. Computer technology will be a major enabler of future naval operations. Computers will enable enhanced situational awareness, realistic modeling and simulation, faster warfighting decisions, more effective weapons, lower-cost platforms, and more efficient and effective use of people. The Department of the Navy should exploit the continual evolution of commercial computer technologies into robust computational systems.
3. The Department of the Navy should undertake early exploitation of the new innovations in commercial communication satellites and fiber optics to acquire the necessary increased bandwidth and diverse routing for future networking needs.
4. Naval operations are increasingly dependent on enhanced sensor data to provide situational awareness, target designation, weapon guidance, condition-based maintenance, platform automation, personnel health and safety monitoring, and logistic management. The Department of the Navy should provide continuing support of sensor technology for areas critical to future naval operations. Special attention should be given to applications of microelectromechanical systems technology because it offers the advantage of low-cost, high-capability systems-on-a-chip that will enable future cooperative sensor networks.
5. Automation increases manpower effectiveness and warfighting capability by performing routine functions, conducting superhuman and hazardous operations, and minimizing casualties. The Department of the Navy should field a vigorous program in the technologies for ship automation that will realize these benefits. Unmanned aerial vehicles and unmanned underwater vehicles will play a major role in future naval warfare as surveillance, communication, targeting, and weapon-guidance platforms. The Department of the Navy should support technology developments to increase mission duration and operational capability, enhance sensor payloads, and increase survivability.
6. Economic and social conditions will force the Navy to conduct its future missions with fewer people and lower overall manpower costs. To accomplish this, the Department of the Navy should exploit the technology advances in communications, information, health care, biotechnology and genetics, and cognitive processes to enhance human performance through expanded education and training, improved personal health and safety, and enhanced quality of life throughout the Navy and Marine Corps.

7. Materials are used in every aspect of naval operations. In the future, entirely new and enhanced existing materials will be designed and manufactured using a computational approach in which the physical and mechanical properties of materials are understood on an atomic scale. The nanophase materials engineered in this way will be tailored to meet specific requirements and to be reliable and robust at lower life-cycle cost. The Navy should strongly support the development of this new materials design and processing approach.
8. Direct electric drive for ships and submarines offers unique advantages for the future naval forces in the areas of reduced volume, modular flexible propulsion units, lower acoustic signatures, enhanced survivability, and the enabling of new capabilities. The power and propulsion technologies of efficient gas turbine propulsion units, modular rare-earth permanent magnetic motors, and power control modules have matured to the point that the Department of the Navy should place a high priority on the development of new all-electric ships with the associated drive, power-conditioning, and distribution systems
9. Battle-space awareness, communications, target identification, navigation, weapon guidance, and tactical planning all require real-time understanding and forecasting of the atmospheric, space, and sea environments of operation. Global weather models with improved satellite data on winds, temperature, solar inputs, and so on will permit the generation of accurate weather forecasts. Space weather forecasting of solar disturbances, scintillation phenomena, and other disturbances will be modeled based on real-time satellite data.
10. Large-scale processes within the Department of the Navy, such as platform acquisition, logistics management, resource planning, mission planning, and personnel management, are major cost drivers of naval operations. Information technologies are becoming available that can revolutionize the execution of these enterprise processes with a resultant substantial reduction in manpower, cycle time, risk, and cost. The Department of the Navy should strongly embrace and support these information technologies for enterprise-wide processes.
11. Science and technology will continue to be the essential underpinning for maintaining superior Navy and Marine Corps warfighting capabilities. The Department of the Navy should follow a three-pronged strategy: (1) exploit rapidly evolving commercial technologies, such as computer, information, and communication technology, and biotechnology; (2) maintain technical leadership in non commercial areas of naval importance, such as weapons, sensors, oceanography, and naval platforms; and (3) continue to support vigorously those areas of fundamental, long-term basic research, primarily conducted at universities, from which new understanding and new naval technologies evolve.

VOLUME 3: INFORMATION IN WARFARE

1. **Establish and treat *information superiority* as a warfare area.** Provide a mechanism for coordinating all Navy Department command, control, communications, computing,

intelligence, surveillance, and reconnaissance (C⁴ISR) resources, requirements, and planning.

A mechanism must be found to coordinate all aspects of *information superiority* across both Navy and Marine Corps C⁴ISR endeavors, giving due consideration to the evolving missions for naval forces and to current and future capabilities for ISR performed by other Services and agencies. If established, such a mechanism could greatly enhance the capability of joint operations with other services.

2. **Encourage *information superiority* careers.** Educate all officers, regular and reserve, about the information technologies, resources, and systems needed to support future Navy and Marine Corps operations; define a cadre of specialists; and identify a career path to flag/general officer rank.
3. **Adopt commercial information technology, systems, and services wherever possible.** Develop technologies only for special Navy and Marine Corps needs such as low-probability-of-intercept communications and connectivity to submerged platforms. When necessary, develop technologies to fit naval special needs such as those for multiband, multifunctional antennas; communications to undersea platforms; and low-probability-of-intercept and antijam-capable communications systems.
4. **Modernize information systems and services aggressively.** Strive to involve operational users, research commands, and acquisition organizations in a cohesive relationship that allows the continued rapid insertion of advanced information systems for use by Navy and Marine Corps forces. The Navy Department should continue to modify and adapt the acquisition system, in collaboration with the warfighter, to allow accelerated demonstrations of advanced information technologies and the rapid fielding of new information systems. Where feasible, it should adopt commercial systems and adapt naval applications to their capabilities, rather than develop service-unique systems.
5. **Focus information infrastructure R&D.** Make integration of diverse commercial services and DOD-unique links a primary focus of information infrastructure and network research and development. The Navy Department should pursue selected R&D focused especially on cross-network interoperability, involving commercial-to-military communication and interoperability, civil-to-military and military-to-military, such that seamless integration and transfer between these networks is easily achieved (air and space communications to submarines is a good example).
6. **Manage data sources.** Establish a clear policy designating responsibility in the Navy Department for identifying, organizing, classifying, and assuring all relevant information sources that permit information extraction and communication from multiple remote locations. Invest in research on and development of tools and techniques to facilitate this shared information environment. Ensure timely and convenient access to all relevant information sources by naval assets.
7. **Extract relevant information and knowledge.** Adopt commercial data-mining technology for naval applications and pursue a theory of information understanding and apply it to target recognition. Establish naval expertise and fund data-mining technologies from commercial technologies adopted for naval applications. In

conjunction, emphasis should be placed on stimulating advances in recognition theory for the extraction of critical understanding and information.

8. **Exploit commercial sensing.** Consider commercial space-based imaging systems and tools for exploiting them, as well as mechanisms for distributing data, in support of naval applications. The DOD and the Department of the Navy should adopt acquisition strategies that take maximum advantage of the capabilities provided by commercially available space- and airborne imaging systems and should seek to exploit spin-offs of commercially developed sensor technology for application to military-unique applications.
9. **Exploit National and joint sensors.** Provide online/direct connectivity to naval platforms and Marine Corps units to support long-range and precision-guided munitions. The Department of the Navy must continue to integrate naval sensor systems with National and joint systems to provide near-real-time wide-area surveillance and target identification in support of force projection ashore. Investment should be made to provide digital connectivity and direct downlinks to support robust C⁴ISR, as well as sensor-to-shooter architectures for long-range and precision-guided munitions. When early external support cannot be ensured, the Department of the Navy should consider the development of organic sensors to sustain *Forward ... From the Sea* dominance.
10. **Make information warfare operational.** Integrate defense and offense and develop needed technology, systems, tactics, tools, and intelligence support. To develop the capabilities required for information warfare in 2035, the Department of the Navy should continue to make information warfare activities operational by integrating defensive and offensive elements at the control of the warfighter and by investing in the development of specific technology for support of countermeasures and defensive capabilities, offensive tools and tactics, and intelligence capabilities.

VOLUME 4: HUMAN RESOURCES

Eight strategic objectives that the NSB believes deserve the attention of the Chief of Naval Operations (CNO) if our nation's naval forces are to develop and maintain the human resources—the human performance and competence—they will need to meet the challenges of the 21st century. The eight strategic objectives are as follows:

1. Recruit a higher proportion of people with above-average abilities, including already trained people through lateral entry, and retain high performers for longer periods.
2. Reduce the numbers of sailors required on ships and ashore, and increase their performance by investing in their professional development and personal well-being.
3. Emphasize education for officers as an essential part of career development, especially education in science and engineering.
4. Invest more in the conversion of conventional forms of training to technology-based, distributed training.

5. Provide for significant advances in the development and application of medical technologies for reducing combat casualties and deaths.
6. Strive for a duty, career, and personal life environment that increases retention, enhances readiness, and promotes performance.
7. Invest more in people-centered research to support the introduction of useful new technologies and to increase efficiency.
8. Develop a more integrated system for managing people in response to advancing technologies, in order to increase efficiency and improve readiness.

VOLUME 5: WEAPONS

1. **Surface-to-surface** (also applicable to subsurface-to-surface and air-to-surface): a family of low-cost, high-volume, long-range precision ballistic weapons; and
 - **Air-to-air**: a new weapon to support a long-range engagement capability that exploits airborne cooperative engagement capabilities (CECs).
2. **Air-to-surface**: continue the trend toward smart precision standoff and direct-attack munitions.
3. **Cruise missile defense/antiballistic missile (CMD/ABM)**: continue the pursuit of an integrated, all-platform, multilayer defense with a variety of weapons.
4. **Undersea warfare**: weapons optimized for offensive and defensive operations in littoral regions.
5. **Offensive/defensive mine warfare**: mines operated by networked sensor systems.
6. **Special techniques**: emphasize special lethal and less-than-lethal warfare techniques as well as an integrated WMD defense.

VOLUME 6: PLATFORMS

Ship Technology Recommendations

1. To minimize manning, increase reliability and survivability, enhance system upgradability, and reduce life-cycle costs, develop and introduce component-level, intelligent, distributed ship systems automation technology, including the following:
 - Microprocessor-based intelligent sensors and actuators;
 - Reliable secure communications at all levels, including peer to peer;
 - Intelligent operation, monitoring, maintenance, and damage control doctrine; and
 - Commercial open architecture systems adaptations.
2. Aggressively pursue integrated electric drive integrated power and propulsion systems; develop and exploit quiet, high-density permanent magnet propulsion motors; exploit

advances in semiconductor technology to develop power electronic building blocks; and begin at-sea testing and evaluation of system performance. These approaches offer high potential for reducing signatures and decreasing life-cycle costs.

3. Expand signature reduction initiatives in the following areas:

- Composite materials,
- Advanced hydrodynamics and power systems,
- Closed-loop degaussing, and
- Advanced hull forms.

Air Technology Recommendations

1. Pursue technologies that reduce takeoff and landing footprints and improve the payload range and the endurance of manned and unmanned air vehicles:

- Slow-speed laminar flow control;
- High-lift aerodynamics;
- Lightweight, high-strength composites;
- Core engine performance enhancement;
- Variable cycle engines;
- Small, high-performance, heavy-fuel engines; and
- Integrated flight and propulsion control.

2. Exploit commercial developments in high-capacity, long-range data links.

3. Emphasize technology developments focused on reducing the cost of enhanced survivability.

Submarine Technology Recommendations

1. Exploit the spectrum of payload technologies to provide future submarines with an integrated payload system that is flexible and modular and can covertly carry, launch, and recover a wide range of future weapons, sensors, vehicles, and forces. Develop submarine-launched off-board vehicles, both UAVs and UUVs, for use across all mission areas.

2. Aggressively pursue a stable, extensive R&D program for the continuing analysis and guaranteed quality of submarine stealth. This program must address all aspects of stealth technology, including hydrodynamics, acoustics, nonacoustics, and signal emissions, in an integrated systems approach.

3. Upgrade submarine sensors and their connectivity, thereby improving the submarine's ability to sense, process, and fuse information through the application of rapidly advancing technologies: fiber optics, acoustics and nonacoustics, lasers, high-speed computers, and other innovations.
4. Significantly improve submarine power density as a key to the improvement of payload capacity, warfighting effectiveness, and survivability. The space and weight fraction dedicated to energy production and distribution must be reduced in submarine main power, auxiliary power, weapons, and off-board vehicles.

VOLUME 7: UNDERSEA WARFARE

Antisubmarine Warfare Recommendations

1. Establish and maintain a dedicated long-term program, centered on at-sea measurements and tests, to provide the science and technology bases for pushing active and passive acoustic array gain to the limits imposed by the ocean. Decades of experience have shown that advances in ASW come about only as a result of such programs.
2. Focus passive and active ASW sonar development on exploitation of the ocean's intrinsic coherence and on use of large volumetric arrays, as enabled by massive computational power, miniaturized sensors, and high-bandwidth transmission links, with a goal of 20-dB or greater detectability gains beyond near-term programmed improvements.
3. Develop networked-distributed sensor fields, including unmanned platforms (e.g., unmanned underwater vehicles (UUVs), unmanned aerial vehicles (UAVs), and satellites), for both submarine detection and local environmental characterization.
4. Develop weapon concepts and technologies that will exploit distributed sensor networks, permit rapid response, and provide more capability against countermeasure-equipped quiet submarines and torpedoes.

MINE WARFARE RECOMMENDATIONS

Near Term

1. Implement a factory-to-seabed intelligence, surveillance, and reconnaissance capability, using a full set of ISR methods, including surveillance by satellite, atmospheric and undersea manned and unmanned vehicles, submarines, human intelligence assets, and special forces.
2. Develop technologies that will provide naval forces with organic MCM capability, including helicopter-compatible sweeping and hunting equipment, remotely operated off-board surface or UUV sensors, and on-board MCM sonars.
3. Aggressively pursue the development of so-called brute force technologies that will neutralize mines and obstacles in the very shallow water zone, the surf zone, and the craft landing zone.

Far Term

1. Develop technologies for advanced networked sensor and weapon systems consisting of the following:
2. Autonomous and semiautonomous networked undersea systems using small, autonomous undersea vehicles, bottom-crawling variants, and fixed sensors for far-forward covert MCM; and
3. Controllable mines with remote fail-safe command and control (C²) and selective targeting.
4. Develop next-generation MCM ships as small platforms capable of sea state 4 operation, carried by a mother ship capable of battle group speeds. Develop the lightweight hunting and sweeping technologies required for these smaller units.
5. Apply reasonable mine shock hardening and effective acoustic and magnetic signature reduction technologies to all new-construction ships.

VOLUME 8: LOGISTICS

1. The Navy and Marine Corps should take the opportunity now, before starting the design of new logistic ships, to define and design future logistic processes, from the sources of materiel to its delivery in warfighter-ready condition to naval forces at sea, from the sea, and over the shore.
2. The Navy and Marine Corps should learn how to exploit the advantages of standard shipping containers in supporting naval forces at sea, from the sea, and over the shore. Containers offer efficiency, control, and security in transporting and handling materiel. With emerging technology for load planning, content tagging, and shipment tracking, containers can be transformed from dumps of randomly stowed materiel to virtual supply depots of immediately accessible materiel that is warfighter ready.
3. The Navy and Marine Corps should develop and apply to logistic operations the emerging information technologies that promise to enable management of processes as integrated enterprises supporting naval operations:
 - Automated marking and identification technology to eliminate manual input of critical logistic data;
 - Sensors and intelligent software for monitoring logistic activities (e.g., shipments and maintenance) and for carrying out routine actions automatically;
 - Displays and software for assimilating, presenting, and making easier to use the vast quantities of data;
 - Modeling and simulation, for real-time planning, assessment, and selection of courses of action; and

- Distributed collaborative planning, for rapid coordination of resupply actions among the supplier, the transporter, and the user.
4. The Navy and Marine Corps should formulate and commit to a long-term plan—a path of evolution—to guide technology development, investment, and fleet implementation of a standard integrated, information-based process for maintaining weapon system readiness. The plan should give particular attention to current weapon systems, to infrastructure and common support needs, to integration of industry capabilities into the process, and to developing and exploiting the capabilities of the following technologies:
 - Integrated digital weapon system databases;
 - Computer-based technical training;
 - Integrated maintenance information systems that tie together information relevant to a technician's task and present it at the point of use in the most usable form;
 - Sensor-based diagnostic and prognostic software; and
 - Automated identification, tracking, and control of parts, supplies, and shipments.

VOLUME 9: MODELING AND SIMULATION

Joint Models

1. It is likely that first-generation versions of JSIMS and JWARS will not be satisfactory—even with heroic efforts and even though the products will have many excellent features. There will be major shortcomings with respect to both content and performance. Consequently, the panel recommends that the Navy insist that DOD and the program offices adopt open-architecture attitudes that will promote rather than discourage substitution of improved modules as ideas arise from the research and operations communities, and that they build explicit and well-exercised mechanisms to ensure that such substitutions occur.
2. The panel recommends that the Navy advocate an approach to joint-model development that has a long-haul view and an associated emphasis on flexibility.

RESEARCH IN KEY WARFARE AREAS:

Modeling Theory

1. Multi-resolution modeling, integrated families of models, and aggregation-disaggregation. Agent-based modeling and generative analysis. Some of the most interesting new forms of modeling involve so-called "agent-based systems" in which low-level entities with relatively simple attributes and behaviors can collectively produce (or "generate") complex and realistic "emergent" system behaviors.
2. Semantic consistency. Phenomenological representations in different simulations need to interact with one another in distributed simulations. Such interaction is meaningful only

if the representations are "semantically consistent," that is, if there is a shared understanding of what concepts and data "mean." This requires commonality of context and definition (or well-understood translations).

Advanced Methodologies

1. *Characterization of uncertainty.* No matter how careful one is in preparing for a simulation, certain attributes and interactions will have some measure of uncertainty. Often, uncertainties dominate the problem. Methods to track the propagation of uncertainties should be developed since they can lead to large uncertainties in the output of the simulation. This is a particular challenge in heterogeneous, nonlinear dynamical systems, where uncertainties in components can interact in nonintuitive and unpredictable ways.
2. *Exploratory analysis under uncertainty.* Running a simulation for one set of fixed conditions is generally not satisfactory since there are often large uncertainties throughout the system. Even normal sensitivity analysis on a one-variable-at-a-time basis does not suffice because of interaction effects.

Infrastructure, Tools, and Supporting Technology

1. *Intellectual infrastructure.* Scientific and engineering disciplines typically have a mathematical language in which to frame and solve their problems—e.g., the use of calculus for disciplines as diverse as aeronautical engineering and chemistry. In contrast, there is no widely understood and adopted theoretical basis for M&S. To some extent, object-oriented modeling (not programming) is helping here, but in practice it usually deals with only some of the problems. To help create the needed intellectual infrastructure, the Department of the Navy and DOD should cooperate with industry and universities in encouraging the development of theory and the promulgation of standard texts and case studies.
2. *Object repositories and interface standards to enhance reusability and composability.* Object-oriented technology admits the possibility of assembling major parts of simulations to meet the demands of a particular application from sets of stored objects representing entities and processes. Realization of this capability requires being able to manage large numbers of objects and to ensure consistency despite involvement of multiple developers. Such a capability could reduce costs in simulation development and allow flexibility in simulation application.
3. *Explanation/traceability capability.* This capability applies to all phases of the management process. For example, it would help document the source code with multimedia techniques so that one could understand the phenomena being represented, and it would help explain the results of a simulation by displaying the logic trail that led to the results. Realization of this capability would figure centrally in achieving the

verification, validation, and accreditation (VV&A) of simulations, both in the formal sense and to the satisfaction of individual users.

ASSIMILATING AND EXPLOITING M&S

The Need for Strategic Commitment

1. Based on the history of technology assimilation and the specifics of the current situation with respect to M&S, the panel recommends that the Department of the Navy make a strategic commitment to the success of exploiting M&S. As discussed above, the panel believes that the appropriate strategy would place considerable emphasis on warfare areas and cross-cutting modeling challenges, rather than still more emphasis on computer and software technology. To put this more bluntly, if funding tradeoffs are needed within M&S budgets, then the panel recommends giving higher priority to research improving model content rather than programming or reprogramming of current models.

CHAPTER 10.

Sea Power 2030: CNO Strategic Studies Group (SSG) Operational Concept

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SEA POWER 2030: CNO Strategic Studies Group (SSG) Operational Concept

SSG XVII was challenged to survey the future strategic environment that the nation might face, determine how Naval services would best serve the national security needs in that environment, and recommend a way to proceed toward that vision. Key to the vision is the realization of five trends that all point to the increasing value of the maritime regime.

- Land based forces return to CONUS.
- Restrictions on the use of advance bases.
- Rising area denial threat.
- Forward presence (shaping) requirement.
- Wider variety of response options.

The requirement to be rapidly relocatable, provide a powerful force to blunt or resolve conflicts, and sustain itself without reliance on fixed forward infrastructures frames the Sea Power 2030 concept. Sea Power 2030 is an integrated Naval Force that can rapidly project sea-based operationally decisive power without relying on theater ports and airports. Two components of the concept are maritime combined arms and Sea Base 2030.

The maritime combined arms concept provides a construct in which both forces and fires maneuver. Maneuver forces would no longer be limited by constraints on the mobility of field artillery. Navy strikes forces move beyond being merely an enabler, to become a full combat arm in joint power projection. Strike forces move beyond a supporting role to full participation and in some cases become the primary participant in an integrated land battle. Forces and fires that maneuver in concert from the sea, unburdened by land-based logistic requirements, can move throughout the depth and breadth of the battlespace, bringing dramatic increases in combat potential for forces ashore.

The Sea Base 2030 concept gives naval forces the positions from which to project power. As a base of operations, it is where the commander can synchronize all his effects. He can project power, maneuver, regenerate and resupply, maintain an operational reserve, and provide theater protection. Not a fixed location, it is fully mobile and re-configurable. The Sea Base provides the volume and precision of fires and the effects of fires to have an operational impact deep inland and to support tactical maneuvering forces across an expanded battlefield. The sea base also provides sustainment ashore and afloat and is a haven for force recovery and reconstitution. It's a new naval operational art that allows the conduct of the land campaign from offshore. The focus is far less on the holding of territory, but on mobility and a networked distribution of assets to exert control and project power throughout the battlespace. The Sea Base highlights the

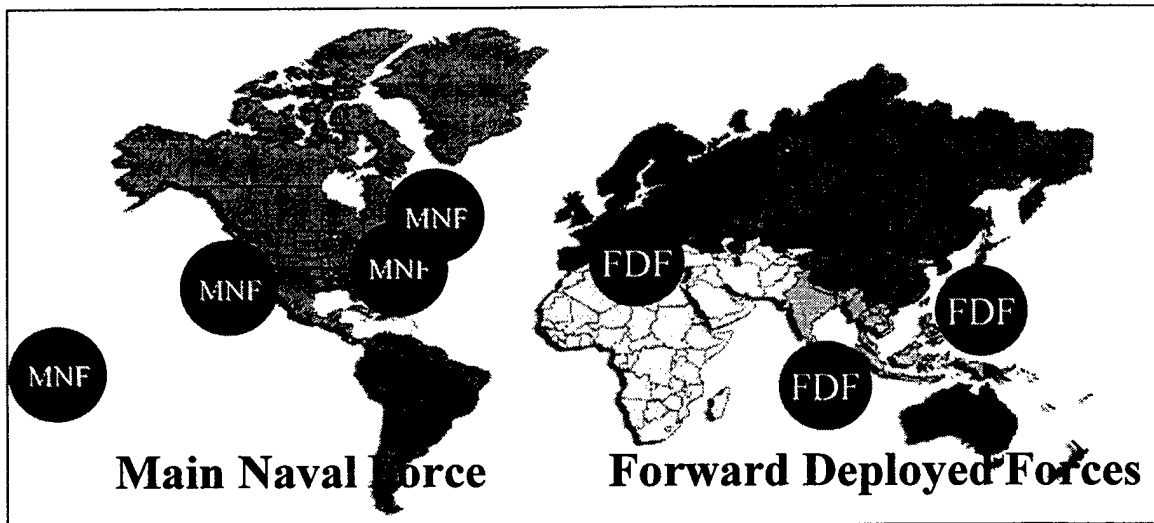
deficiencies of land based campaigning today and the opportunities in Naval Campaigning ashore tomorrow.

The tenets of Sea Power 2030 are that the force is self-enabled, strategically and operationally mobile, not reliant on theater ports or airfields, and possesses operationally decisive power. The force is self-enabled by its self-contained total force package of sensing, C2, troops, fires, and sustainment. This maritime force is connected to and enhanced by national systems and the other military Services. It is a joint force with an important distinction it is not dependent on other forces. It brings a sufficient amount of each capability to operate effectively. It contains the command structure and equipment that make it the logical choice to be the Joint Force Commander's command post. The maritime force is strategically and operationally mobile, going where it needs to go, and moving when required. It is a force that can relocate within a theater of operations, or between theaters using the sea as a means of transport and sanctuary. The maritime force is not dependent on prepositioned equipment. Rather, it is deployable and sustainable without reliance on local infrastructure. If required, it can be supplied directly from CONUS. The maritime force will focus on both the tactical and operational levels of war. The SSG conceived and gamed a system of combat capabilities sufficient to have a decisive, sometimes terminating impact on a wider range of contingencies than naval forces can accomplish today.

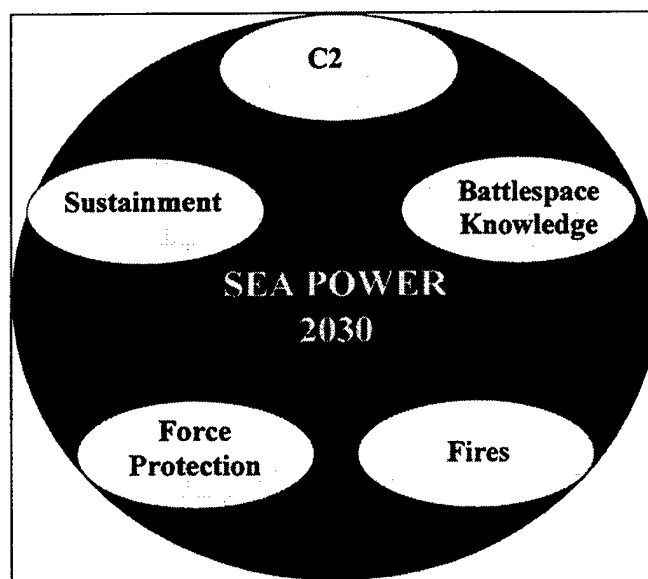
The operational structure is in two echelons, the forward deployed force (FDF), and the main naval force (MNF). The FDF is the first response force and contains a significant warfighting potential. FDFs are deployed with an expanded ability to shape their operating environment, are fully connected to the MNF and to all joint/national assets. The FDF is a tailored/scaleable force that assures access, and is capable of supporting allies and neutrals. In peace, the FDF serves as a conventional presence and deterrent force. It possesses the means to collect and distribute information, thus demonstrating resolve and commitment to friends and allies. It has a shaping capability. In crisis, the FDF is the first U.S. element to establish situational awareness, defend itself and support allies with assured defense (e.g., theater air and ballistic missile defense as examples). In war, the FDF ensures theater access and establishes the sea base in preparation for arrival of the MNF as needed.

The MNF that follows is ready, expeditionary in focus, can quickly deploy, and is committable upon arrival. Able to generate employment options at a higher threshold because of its readiness posture and integrated staff, the MNF may deploy without committing to a single mission. The MNF is the force that answers the requirement to have direct and decisive impact on events ashore. The MNF is built around a capable MAGTF with maritime combined arms, sea based aviation and fires, and logistics support. Its ships will be the bases from which Marines will project power ashore, return when required, and reconstitute for follow-on missions. Speed of response is not just measured in travel time. Of primary importance are not just how quickly the forces can deploy, but rather the speed at which capable, sustainable forces can deploy and be employed. When this force, supported by the sea base, is committed, it is the force that makes the littoral naval campaign a reality. In peace, the MNF is a reservoir of forces for FDFs. A proving ground for equipment and tactics, the MNF is connected to FDFs for situational awareness. In crisis, the MNF is ready to respond upon arrival with mature combat comittable forces capable of influencing the land battle through multiple options and effects. In

war, it brings operationally decisive power to the theater, fighting and supported from the sea utilizing the maritime combined arms approach to warfighting. Finally, the FDF and MNF can both serve as the core force and staff for the surge of follow-on joint forces.



The SSG defined the battlespace functions (command and control, intelligence, movement and maneuver, fires, logistics, and force protection) in terms of new, supporting constructs. Together these redefined operational functions enable the conduct of Sea Power 2030. They must be taken together to give the naval commander of the future the means to plan, conduct and sustain military actions across an expanded range of military options focusing on the land fight.

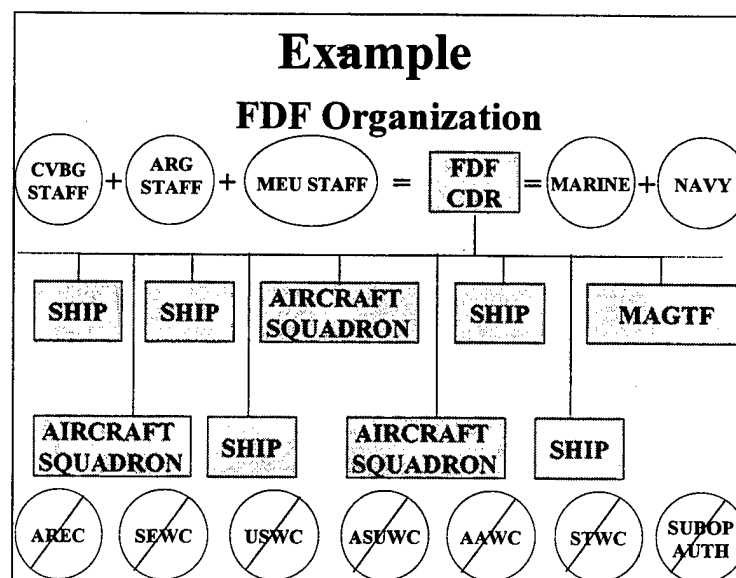


Command and control will be addressed in terms of a new organizational structure. Intelligence will be described in terms of obtaining battlespace knowledge. The expansion of the Sea Base 2030 addresses the logistics battlespace function. Fires and maneuver are combined. Finally, force protection is discussed in terms undersea warfare in the littoral.

C2/Decisions. The SSG proposes a flat, adaptable naval organization. Changes in the Navy's operational concept along with the implications to the command and control of an afloat self-sustaining force capable of decisive impact deep inland will fundamentally alter the character and conduct of future military operations. The Department of the Navy brings to the table unique qualities and capabilities of a maritime and expeditionary superpower. A significant characteristic of this force is the full integration of the Navy/Marine Corps team. It is a single unified organization at the operational, staff, and command levels. These two forces work as a truly integrated operational team and not as two separate entities. All the assets are fully shared, intermeshed, deployed and employed for a single purpose.

The organization will become flat because of three key factors: need for speed in decision-making, capabilities distributed throughout the force and continual improvements in information technology. Growth in the capability of decision support systems and capacity of information flow on the 'net' will abolish the need for middle management and allow for a greater span of control. The elimination of the middle layer will permit the commander and his staff to be closer to the source of information – with fewer layers through which the information must pass. The result is the combining the current day aircraft carrier battle group (CVBG), amphibious ready group (ARG) and Marine expeditionary unit (MEU) staffs into one integrated Navy and Marine Corps operational staff. This yields a very flat organization.

Sea Power 2030 will revolutionize warfare as we know it today. Its flat, adaptable, Naval organization operating with decision support systems in a fully netted environment will lead this force of the future.



Battlespace Knowledge. Battlespace knowledge is more than displaying a common uniform picture of the battlefield. It is having a clear picture of the theater with equal understanding among the warfighters. It is visualizing both friendly and enemy force laydowns, knowing what they are doing, knowing what they are capable of, and most importantly, what they intend to do. Finally, battlespace knowledge is the ability to make rapid combat decisions with greater certainty than was possible before.

The SSG believes that current operations are characterized by:

- No common depiction or understanding.
- Incomplete view of battlespace.
- Inefficient allocation of resources.
- Uncertainty.
- Untimely information exchange.
- Poor assimilation of non-organic sources.
- Low confidence in existing systems.

The SSG believes that shared and equal knowledge is not available either within our battlegroups or throughout the fighting forces. Additionally, the SSG states that our ability to rapidly assimilate intelligence data from non-organic sources and integrate it with our own sensor data is virtually nonexistent. The goal is to provide a common real-time, integrated picture of the battlespace to all the fighting forces and coalition partners. This system will include the fusion of coalition partner sensor systems as well as our own small unit tactical LANs-like those used by our Marine ground units. Historical information will be combined with present sensor information and output from simulation/models to be turned into battlespace knowledge. Battlespace knowledge will allow the commander to allocate resources to exploit anticipated opportunities, or to react quickly in response to unanticipated events. Additionally, these systems will rapidly fuse and correlate data to distinguish noncombatants and friendly forces from the enemy, to understand the enemy's capabilities, and to make well-grounded estimates of his intentions.

As the Navy shifts its focus to littoral warfare, sensor requirements will change dramatically. Supporting urban operations, tracking overland cruise missiles, mobile targets, and finding underground facilities represent some of the missions that the Navy will be called upon to perform. Exploiting the attributes of overland targets differs significantly from a maritime environment, a fact that drives the requirement to develop new sensor capabilities for littoral operations.

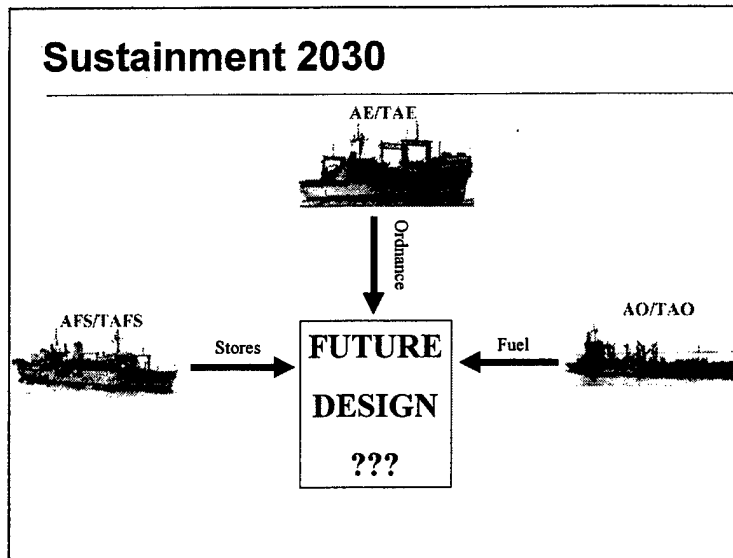
In summary, the systems described go far beyond automating today's processes. The SSG's proposal is a fundamental change in the way the fleet does business; rapidly driving the external national and strategic level information and resources down to the operational level, while simultaneously providing detailed information and an accurate organic tactical picture of the battlespace up through to the commander. This involves a dramatic shift, from the analyst producing time-late, incomplete products from behind the black door; to the fighting forces

having access to a clear, tailored picture of the battlespace allow the warfighter to gain rapid UNDERSTANDING of the battlespace upon which to quickly make confident combat decisions.

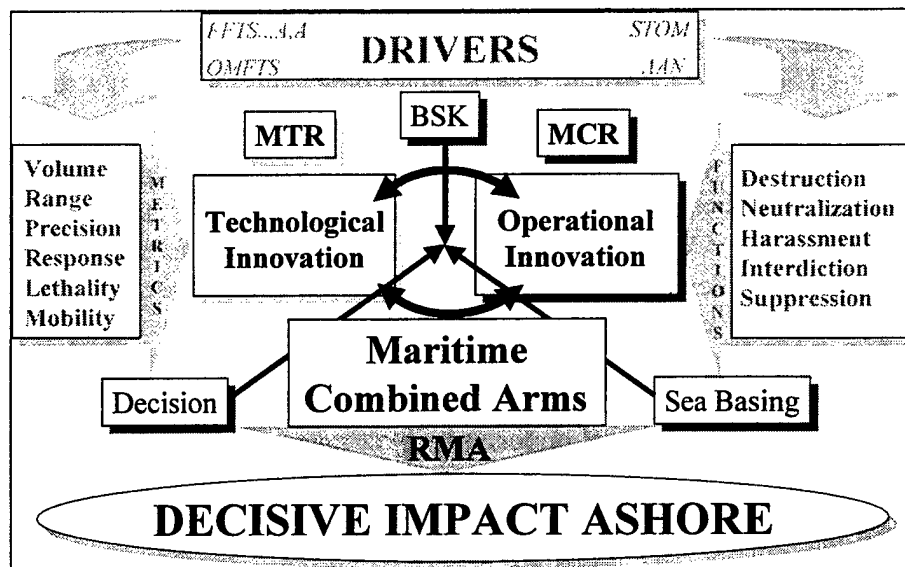
Sustainment; Sea Base 2030. The Sea Base 2030 concept is more than a ship. It includes a physical area and the capabilities embodied in all of the collective assets within that area. It is a fully self-sustaining and self-enabling naval system. It is capable of all naval functions, including battlespace knowledge, power projection, maritime combined arms, and command and control. It sustains those capabilities, as well as the supportive platforms in the sea base. Sea Base 2030 is not reliant on forward land bases, ports, or airfields and eliminates the requirement for maritime prepositioned assets. It is an integral part of the Sea Power 2030 operational concept, integrating all systems. The objective of the concept is to sustain all forces from the sea base. This objective includes sustainment of platforms in the sea base, as well as forces ashore, for the duration of the campaign. Distributed throughout ships in the sea base are sufficient sea-based airlift to sustain, move, and otherwise support the forces ashore.

The SSG felt that the current shuttle ship-station ship method, which depends on multi-stage transfers, adds unnecessary steps to a very complex process. In addition, current transfer mechanisms degrade or eliminate the ability to engage while resupplying. Using an integrated systems approach, solutions that combine all the functions of today's combat logistics force and projections of future requirements were projected into a single future design ship. Some emerging technologies integrated into the design are:

- Robust vertical and surface lift capability.
- Force sustainment and force projection out to 400 nm inland at speeds of 350 kts.
- Full access to stores afloat (loose load).
- Automated astern refueling.
- Modular resupply.
- Laser directed manufacturing.
- Carbon nanotube technology.
- Inertial electrostatic fusion.



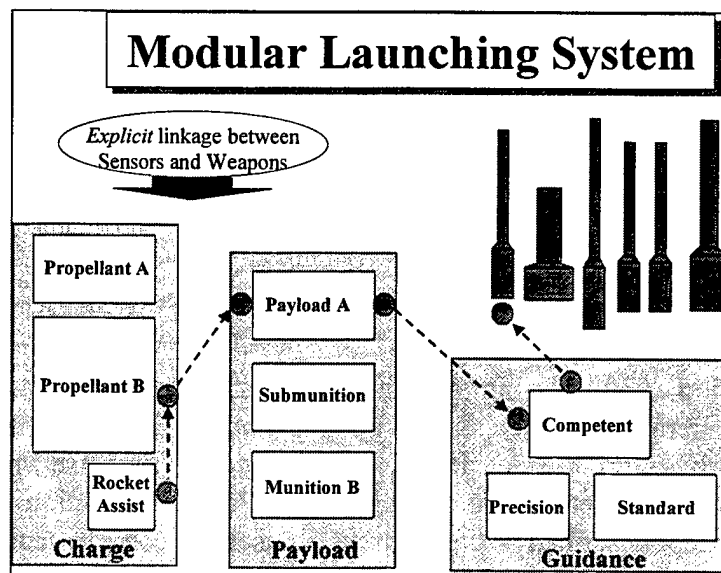
Power Projection 2030. The aim of this concept is to have a decisive impact ashore. Using the current Naval operational concepts (*Forward...From the Sea*, *Operational Maneuver From the Sea*, etc.) as drivers for the Sea Power 2030 concepts, fires are improved and utilized to produce the decisive impact ashore as promised. Power projection 2030 is the maritime combined arms concept described in the opening. It uses the complementary effects of sea based fires and functional targeting for use by forces ashore.



In the SSG's study of weapons and effects, they came to the conclusion that volume, accuracy (vice precision), range, response, lethality, and mobility were the high payoff areas.

Non-lethal weapons provide expanded effects at the operational level of war. They are applicable across the spectrum of conflict. Non-lethal weapons have uses during pre-hostilities

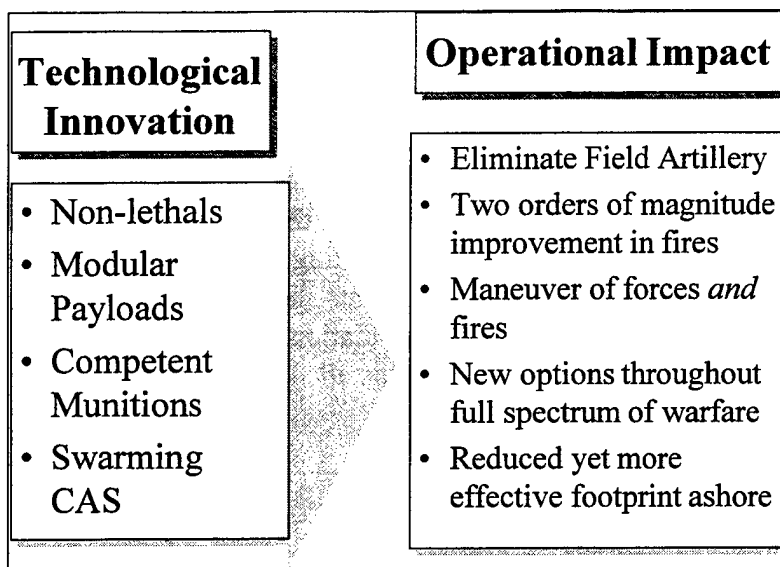
and hostilities. They can limit damage and cause operational or strategic paralysis. Non-lethal weapons that freeze moving parts (possibly delivered by UAVs) can be effective in peacekeeping operations to render artillery, tanks and other combat vehicles inoperative. In combat, they can produce the effects of massed fires, either fixing the enemy or forcing him to move. Ships may be able to produce a high power converging Zenneck surface wave.



The SSG felt that missiles had decreasing marginal returns as plotted against the cost of investment. Modular payloads using VGAS and ERGM netted more effectiveness for the investment dollar. Therefore, utilizing existing main battery gun mounts, a modular launching system would produce cost effective, responsive fires.

To solve the dilemma of providing responsive fires, within two and one half minutes of request, the **swarming CAS** concept is offered. Swarming CAS uses a combination of aircraft and UCAVs. Orbiting UCAVs are on station initially to provide the early response. Manned aircraft are launched from their bases and arrive on scene to offer greater flexibility and ordnance effects. Swarming CAS is enabled by netted warfare, its missions are adjusted near real time, and offer a new level of ground force fire control using observer directed precision guided munitions. UCAVs are a force multiplier. They offer cost savings, are an option for high threat environments, and offer a unique naval opportunity over manned aircraft.

The operational impact of the technological innovations discussed above are summarized in the graphic below.



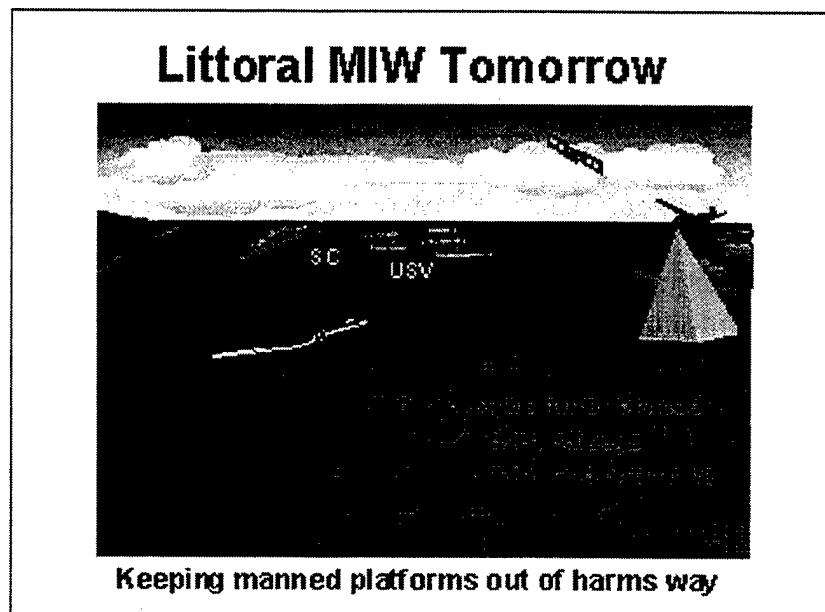
Undersea Force Protection. The undersea warfare concept generation team addressed the challenge of providing force protection to the sea base from undersea threats of 2030. Their work is an extension of last year's SSG work on net-based ASW. The expanded role of the Navy in the littoral will result in ships being dispersed over broader ocean areas and assigned increased responsibilities for missions such as strike, theater air defense, and ballistic missile defense. The demands of these missions will frequently be incompatible with today's methods of conducting undersea warfare. The slow speed of today's techniques make platform based undersea warfare very inefficient and constraining. To meet these challenges a radically different approach to undersea warfare is envisioned. The tie between sensors and manned platforms is severed.

Recent studies in the area of anti-submarine warfare along with other fleet tests demonstrate the ability of multistatic active acoustics to achieve two orders of magnitude improvement over today's passive systems. Non-acoustic wide area search adds a synergistic capability to detecting undersea threats. Together with multistatic active acoustics, these sensors will form the backbone of the system. Undersea warfare will be conducted with remote sensors deployed from manned platforms but moored to the sea floor or carried on autonomous vehicles. Manned platforms are not tied to these sensors. Information processing using fully automated system technology (FAST) will perform automatic target recognition, fusion and correlation, risk assessment, sensor search planning, asset allocation, and sensor system management at a faster speed than today and with fewer people. By netting the sensors as described, domination of the littoral undersea environment--regardless of the location or mission assignments of submarine and surface combatants--is achieved.

Some technologies that will enable the tie between sensors and manned platforms to be severed are:

- Bottom-moored arrays (tethered to or sitting on the sea bottom) that are compatible with standard sonobuoy deployment systems
- Leave-behind **active sources** the size of a lightweight torpedo.

- Sea bottom acoustic receivers.
- Volume arrays for deeper water such as an inflatable cylindrical sensor.
- Active and passive array elements will be capable of communicating on an RF or acoustic network. RF links capable of interfacing with low earth orbit satellite systems or with an autonomous air vehicle theater communications will act as their relay. Unlike today's systems, no connecting fiber or cable is needed between array elements. A few dozen such array elements should be capable of monitoring an ocean area 100 by 200 nautical miles. Installation of sensors could be conducted using aircraft in three to four hours. Once installed, the sensors would quickly locate any hostile submarine in the monitored area.



Recommendations

These are the SSGs recommendations from Sea Power 2030:

1. Develop an overall program to design, experiment and validate integrated command and control organizations, related processes and decision support systems in a fully netted warfare environment. The proposed Navy sponsor should be N6.
2. Develop Battlespace Knowledge concept. The sponsors should be N6 (lead), N091, SSG, NWDC, and DARPA.
 - The Maritime Battle Center to plan and conduct a Fleet Battle Experiment to demonstrate the ability to deploy advanced, self-organizing sensors, and search a littoral area under the control of a Sensor Management System.
 - A combined effort by the Naval Warfare Development Command, DARPA, and follow-on SSGs to develop the specific strategy, operational concepts, and sensor requirements to meet the challenges of overland targeting in the littoral, especially

moving targets. The SSG recommended that the Naval Research Laboratory be designated to coordinate the research and development of sensor systems tailored to this environment.

3. Adopt the Sustainment 2030 concept to achieve a sea-based capability that can fully function without in-theater ports or airfields.
 - Refine our analysis of the strategic lift and logistic requirements of the force.
 - The Sustainment 2030 concept capabilities were packaged into a common hull design that offers significant savings over the evolutionary force. This design deserves continued study.
 - This study presumed that sustainment requirements were reduced by achieving the Cognitive Sustainment capabilities proposed by SSG 15 and SSG 16. Their concepts require continued development to achieve the full potential of this force.
4. Establish Maritime Combined Arms as a new naval mission.
 - NWDC develop Maritime Combined Arms concept as a priority.
 - Bring non-lethal weapons into the mainstream.
 - Invest in the gunnery S-Curve.
5. Develop the Fast and Autonomous Undersea Warfare concept and the technologies necessary to enable it. The proposed sponsor should be N-84.
 - Conduct focused research and development leading to the following automated technologies:
 - Automatic target recognition, fusion and correlation, risk assessment, and sensor search planning and management capabilities.
 - Wide area non-acoustic technologies for submarine and mine detection.
 - Long endurance low frequency active sources and fiber optic arrays.
 - Continue research and development of wide area non-acoustic technologies to search for submarines and mines.
 - Continue to support research on long endurance low frequency active sources and fiber optic array technology.
 - Conducting Fleet Battle Experiments to evaluate operational employment of the following concepts:
 - A quickly deployable, bottomed moored, multistatic active acoustic system.
 - A mobile, modular multistatic active acoustic system, carried on autonomous unmanned surface vehicles.
 - Decision aids integrated with the sensor network to support undersea warfare planning and execution.

Sea Power 2030

Operational Concept

CNO Strategic Studies Group

Expectations and Trends

- ◆ Land based forces return to CONUS
- ◆ Restrictions on use of advance bases
- ◆ Rising area denial threat
- ◆ Forward presence shaping requirement
- ◆ Wider variety of response options

Increasing value of maritime regime

Concept

An integrated Naval Force that can rapidly project sea based, operationally decisive power without relying on theater ports and airports.

Concept Components

- ◆ Maritime Combined Arms
- ◆ Sea Base 2030

Maritime Combined Arms

- ◆ Forces and fires Maneuver
- ◆ Naval Fires support operational and strategic maneuver
- ◆ Dramatic increase in combat potential for forces ashore

Sea Base 2030

“It is power plus position that constitutes an advantage over power without a position...” A.T. Mahan

- ◆ Re-Conceptualized Maritime Theater of Operation
- ◆ Offshore Base of Operations
- ◆ Offshore Firepower Reservoir
- ◆ Offshore Advanced Base
- ◆ New View of Battle Space Control

Concept Tenets

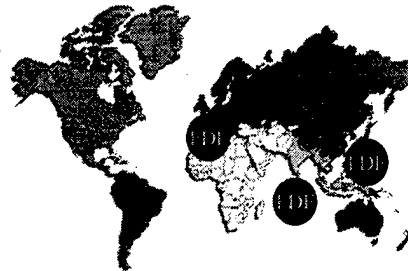
- ◆ Self-enabled
- ◆ Strategically and Operationally Mobile
- ◆ Not reliant on theater ports and airports
- ◆ Operationally Decisive

Operational Structure

- ◆ Forward Deployed Force (FDF)
- ◆ Main Naval Force (MNF)

Forward Deployed Force

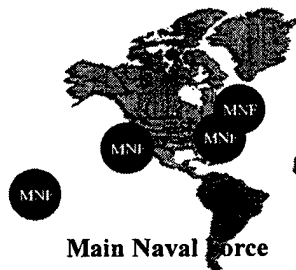
- ◆ Fully Integrated
- ◆ "Horizon"
- ◆ Tailored
- ◆ Consistent Regional Coverage



Forward Deployed Forces

Main Naval Force

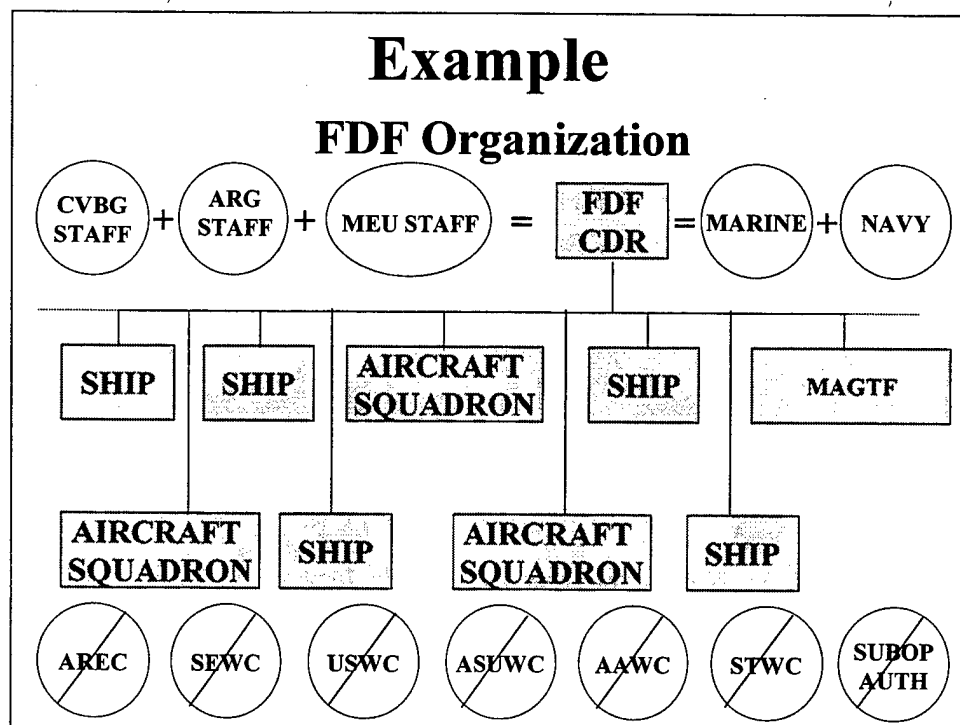
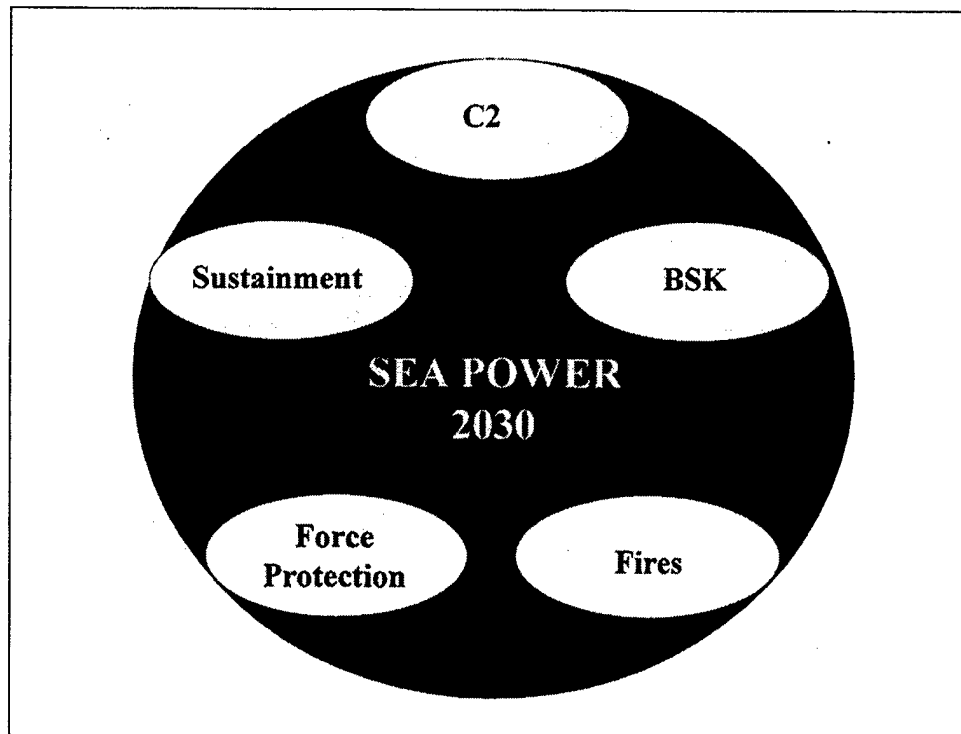
- ◆ Scalable and Expeditionary Force
- ◆ Response to anywhere
- ◆ Mature, combat committable on arrival
- ◆ Fights from the Sea Base



Main Naval Force

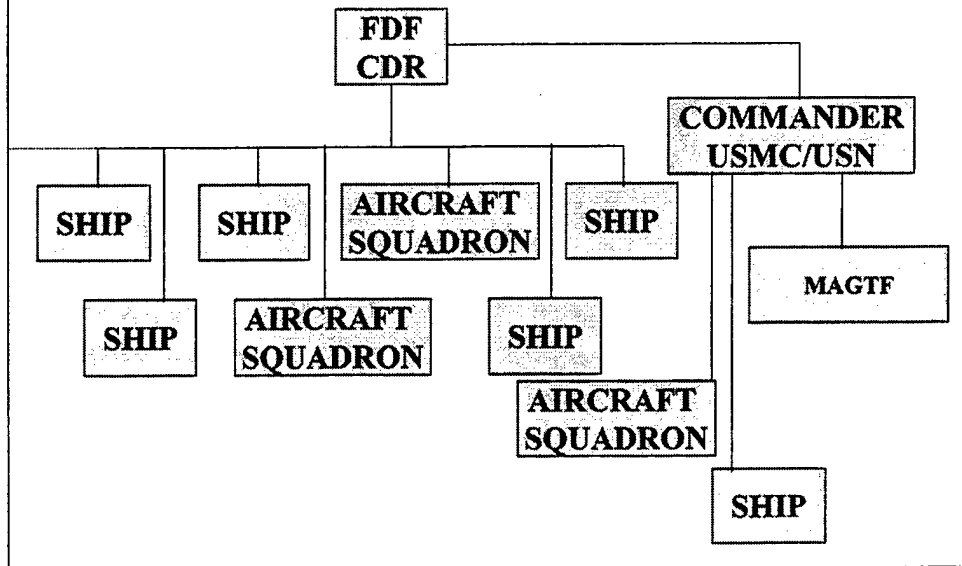


Forward Deployed Forces



Example - Assault Mission

Force is Task Organized



Recommendation

- ◆ Develop an overall program to design, experiment and validate integrated command and control organizations, related processes and decision support systems in a fully netted warfare environment.
 - Proposed Navy Sponsor - N6

Battlespace Knowledge in 2030

**Automated
Prediction &
Understanding**

**Anticipatory
Planning**



**Real-time
BDA**

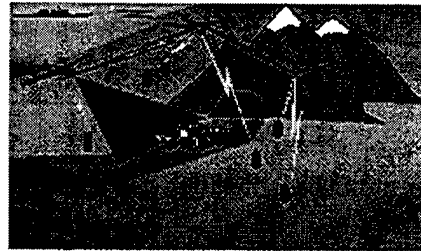
**Battlespace
Deconfliction**

**Real-time
Situational Awareness**

Littoral Warfare Sensor Requirements



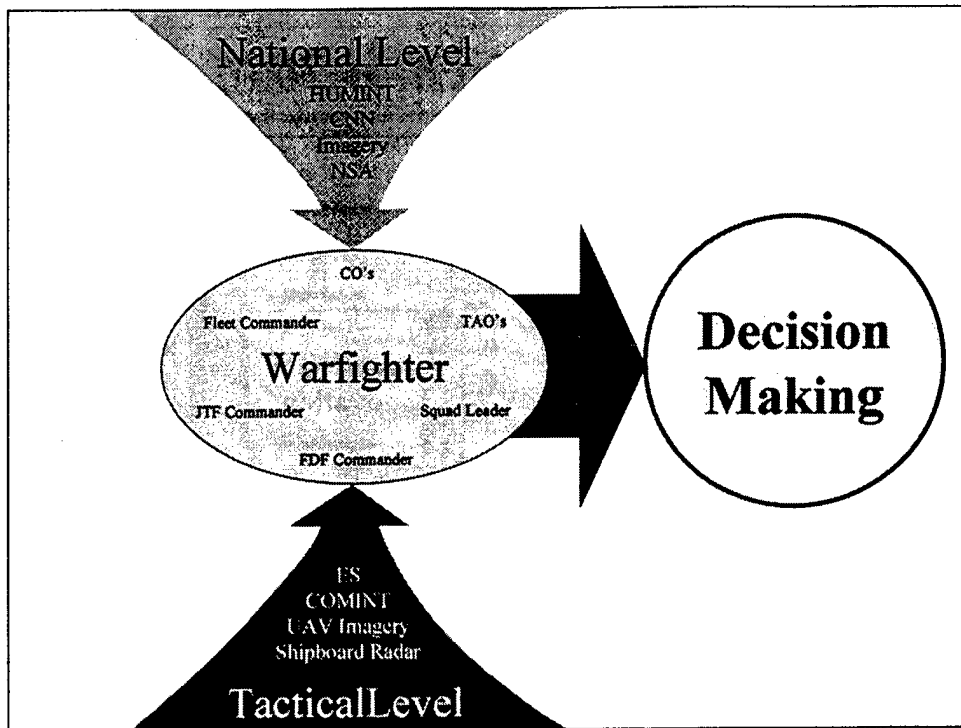
Urban



Underground

**Mobile
Targets**





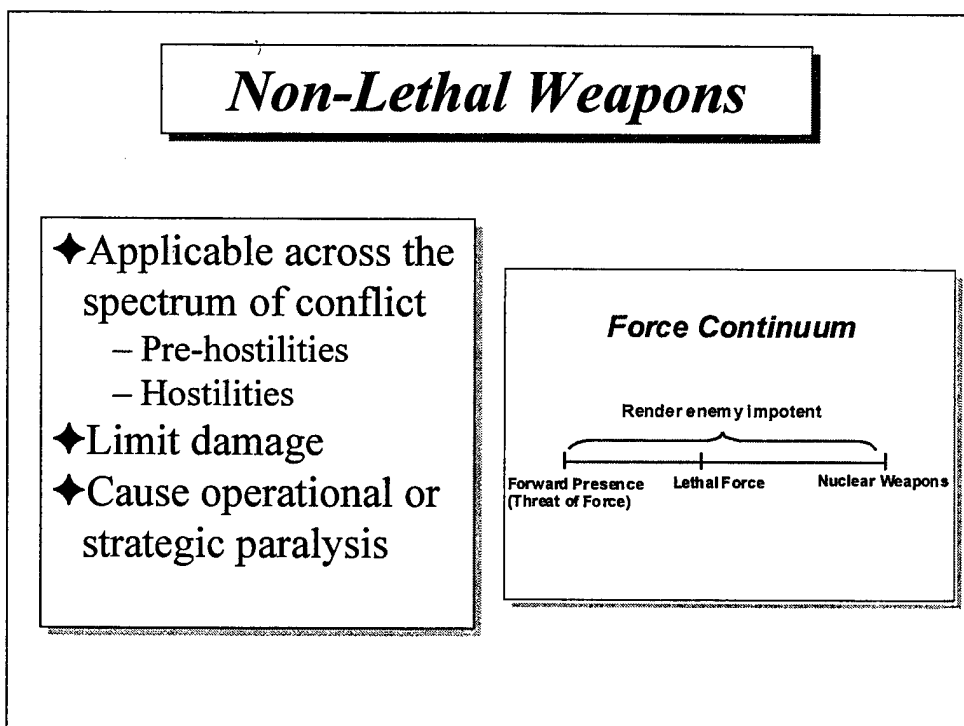
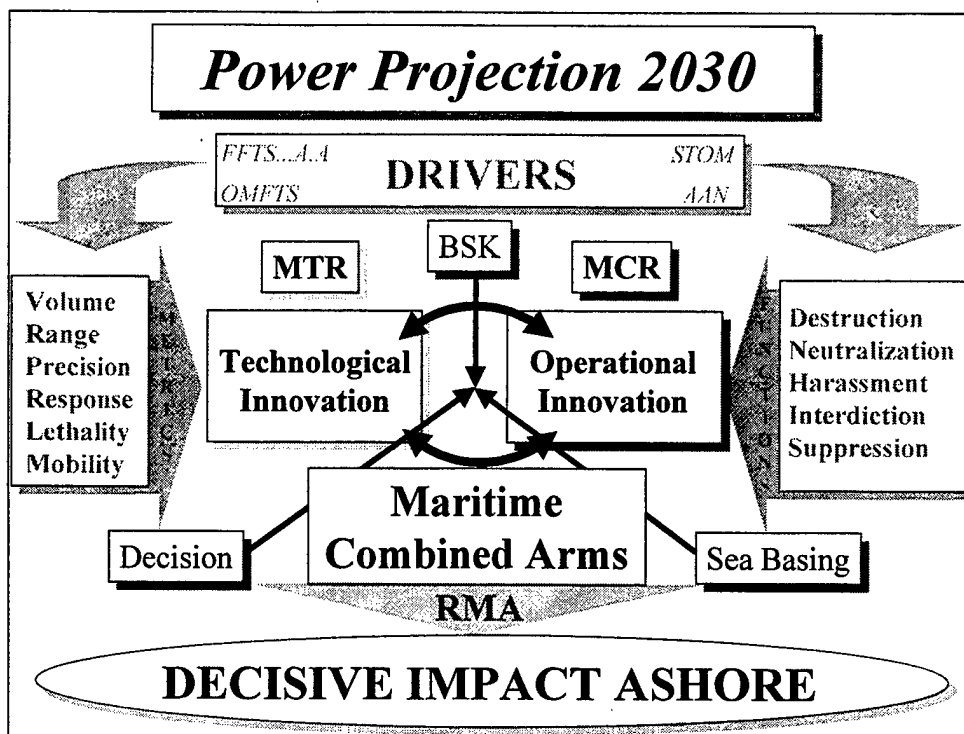
Recommendation

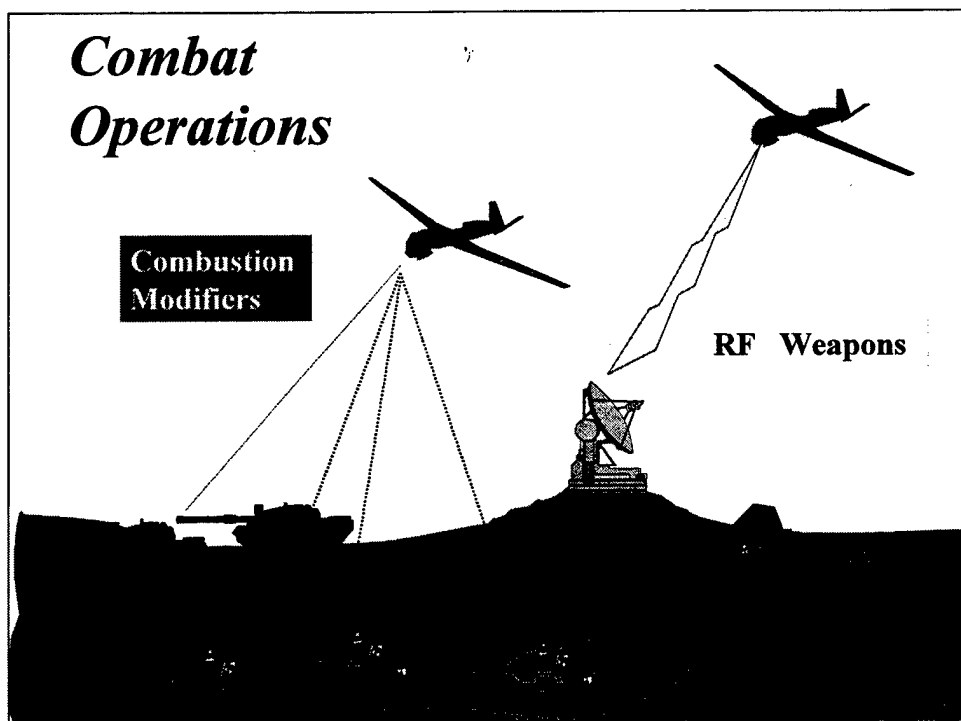
Develop Battlespace Knowledge concept.

(N6 (lead), N091, SSG, NWDC, DARPA)

Next steps

- ◆ Promote continued research of the Dynamic Database System.
- ◆ Conduct FBE to demonstrate autonomous sensor management and self-organizing / self-adapting sensors.
- ◆ Develop specialized sensors for use by Naval forces in littoral environment.
- ◆ Land Targets



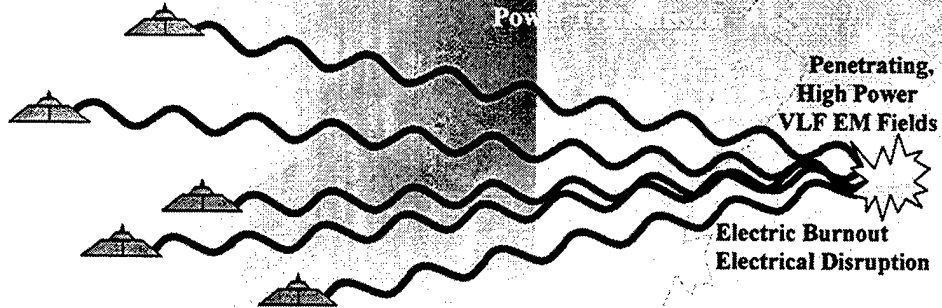


Forcing Function to Augment Fires

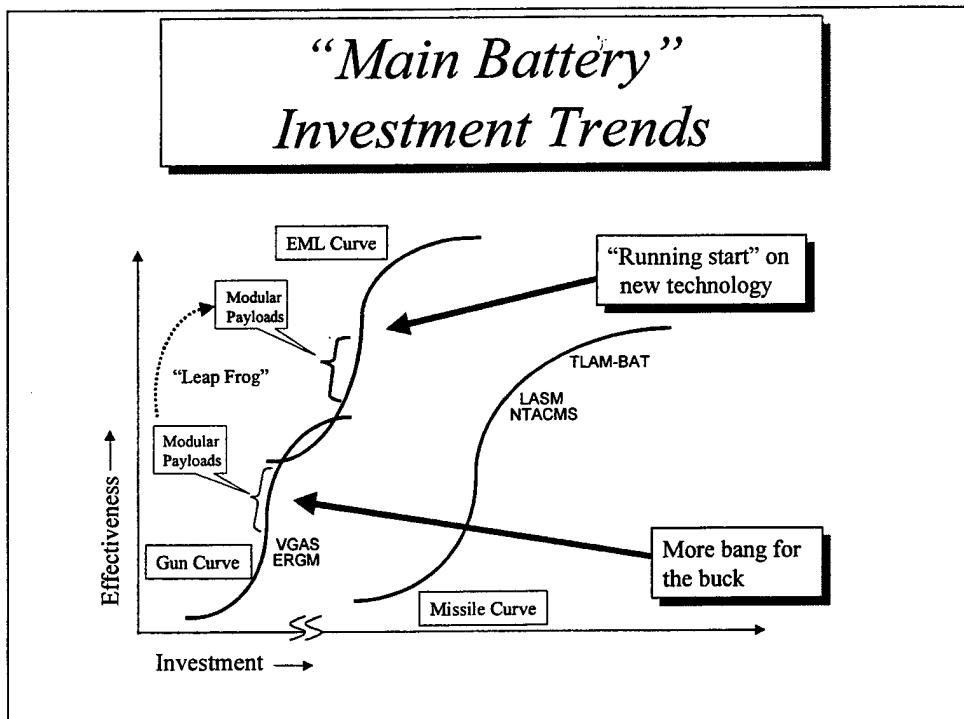
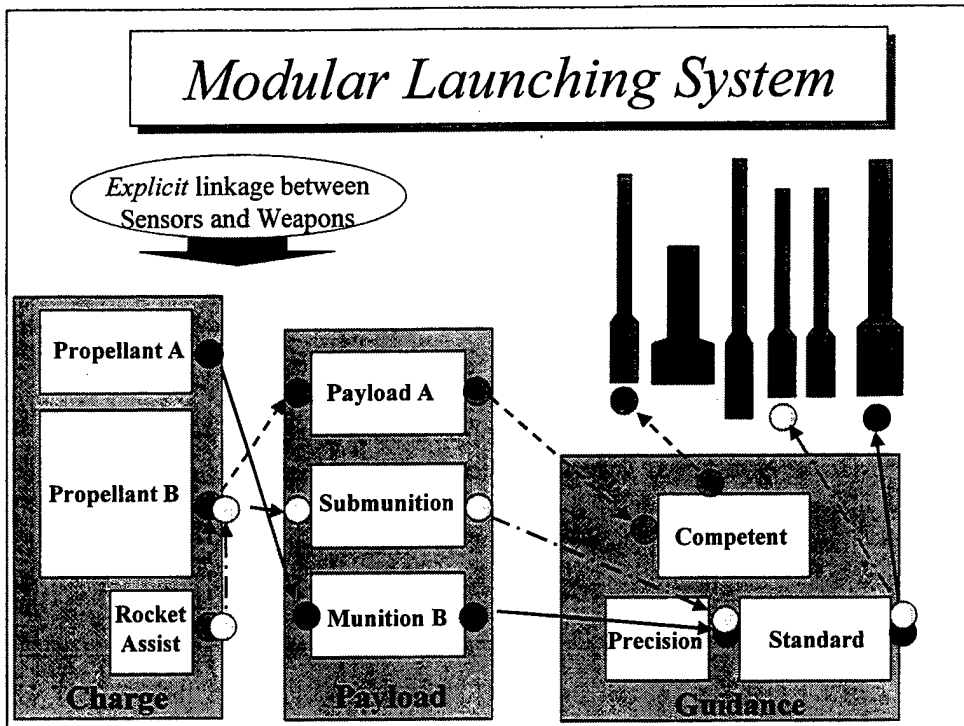


Zenneck Array Weapon Concept

Dispersed Electric
Drive Ships act as
Phased Array



High Power Converging Zenneck Surface Wave



Recommendation

◆ **Establish Maritime Combined Arms as a new naval mission**

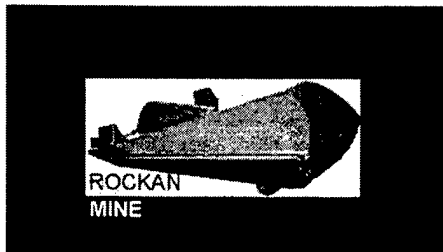
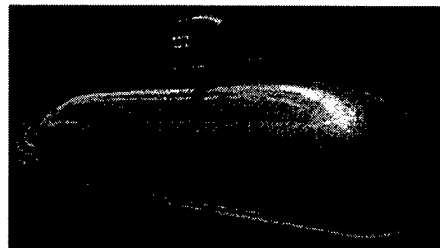
Next Steps

- ◆ NWDC develop MCA concept as a priority
- ◆ Bring Non-lethal Weapons into the mainstream
- ◆ Invest in the gunnery S-Curve
- ◆ Experiment with Swarming Close Air Support

SSG XVII

Undersea Force Protection

**Fast and Autonomous
Undersea Warfare**



Agenda

- **Warfare Challenges**
- **USW Today and Tomorrow**
- **Sensor Employment**
- **Information Processing**
- **Recommendations**

Recommendation

Develop the Fast and Autonomous Undersea Warfare Concept and the technologies necessary to enable it.

Proposed Sponsor: N-84

Next Steps

ONR - Research Enabling Technologies

- ◆ Automatic target recognition, fusion and correlation, risk assessment, and sensor search planning and management capabilities
- ◆ Wide area non-acoustic technologies for submarine and mine detection
- ◆ Long endurance low frequency active sources and fiber optic arrays

Next Steps

NWDC - Evaluate operational employment of the following concepts:

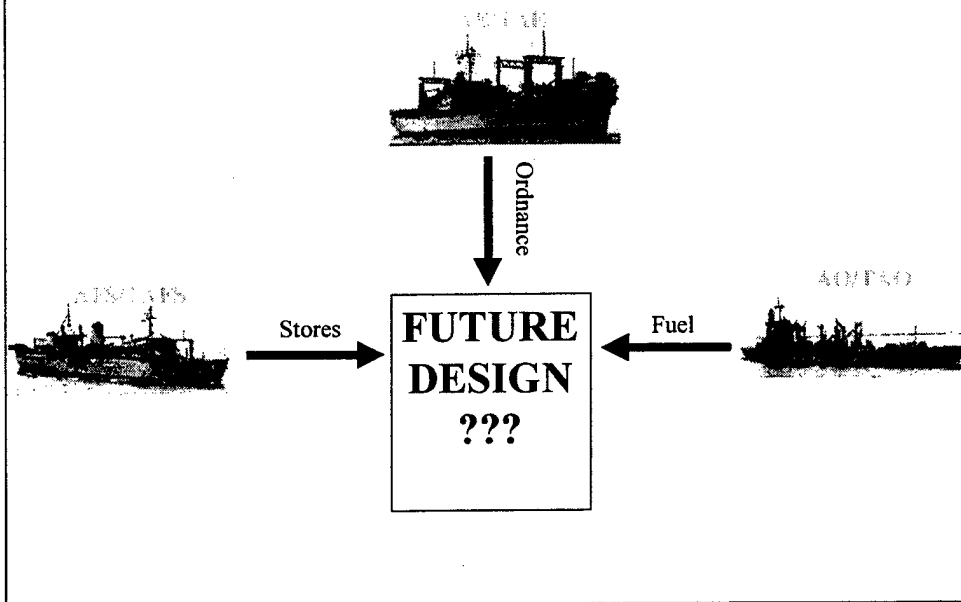
- ◆ A quickly deployable, bottomed moored, multistatic active acoustic system
- ◆ A mobile, modular multistatic active acoustic system, carried on autonomous unmanned surface vehicles
- ◆ Decision aids integrated with sensor network to support undersea warfare planning and execution

SUSTAINMENT 2030

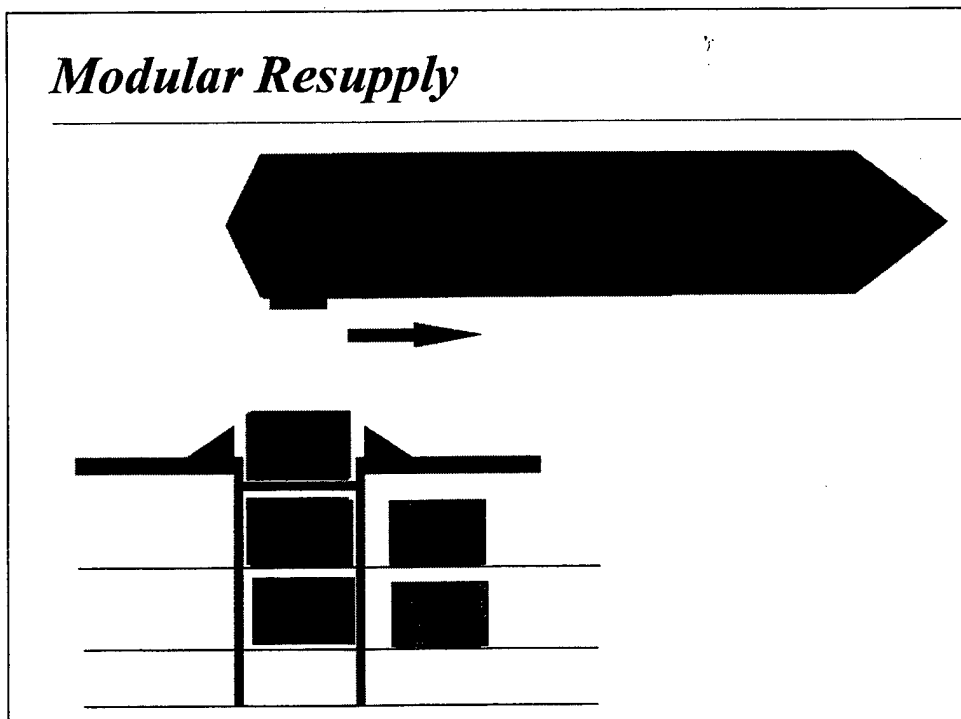
**“THE BEST WAY TO PREDICT THE FUTURE IS TO
CREATE IT.”**

PETER DRUCKER

Sustainment 2030



Modular Resupply



Recommendations

**Adopt the concept of Sustainment 2030
for the support of all forces in the Sea Base.**

Next Steps

- ◆ Refine lift and logistic requirements
- ◆ Re-examine common fleet architecture
- ◆ Continue development of Cognitive Sustainment capabilities recommended by SSG XV and XVI

Summary

Recommendations

- C2/Decisions
- Battle Space Knowledge
- Fires
- Force Protection
- Sustainment

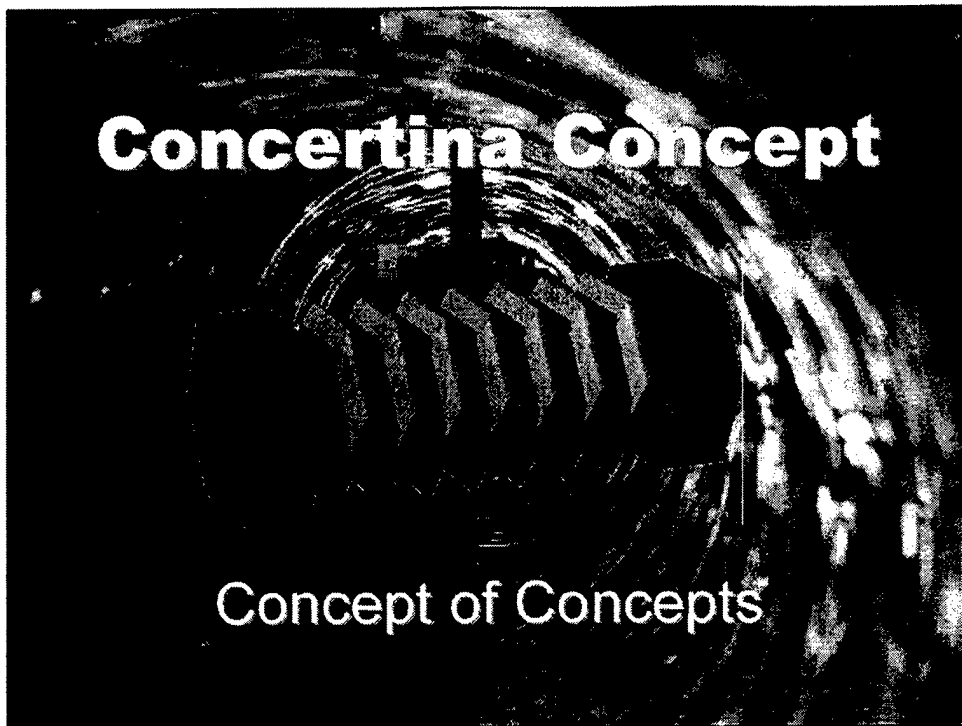
Concept Components

• Maritime Combined Arms
• Sea Base 2030

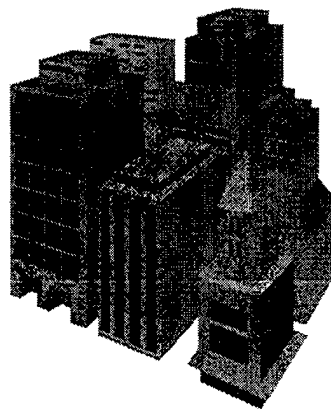
SEA POWER
2030

CHAPTER 11.

Marine Corps Study on Concertina Concepts



**Proposal for the 1998 Defense
Science Board
(Draft Concept)**





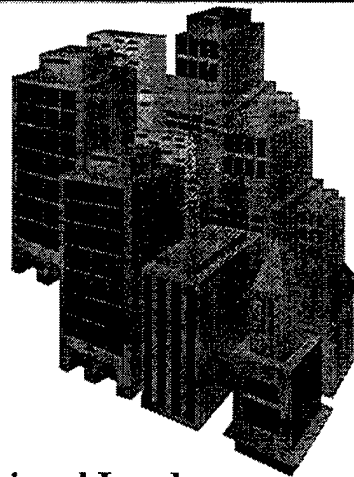
Problem

- How to take advantage of the strengths of many operational concepts
- How to rapidly Expand and Contract a Force to Meet the Demands of a Fluid Conflict in a Multi-Dimensional Landscape
- Construct a force that is Deployable, Redeployable and Reconfigurable; a force that can disperse and mass rapidly.
- How to deal with multiple events simultaneous over time, each in different stages.

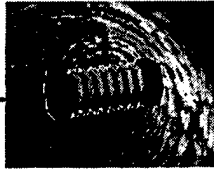


World Environment

- Urbanization**
Asymmetric foe
Rapid tempo
Non-state actors
- Cross boundary cultures
 - Contractors



Result is a Multi-dimensional Landscape



Multi-Dimensional Landscape

The modern battlespace has multiple levels of Warfare occurring simultaneously, producing non

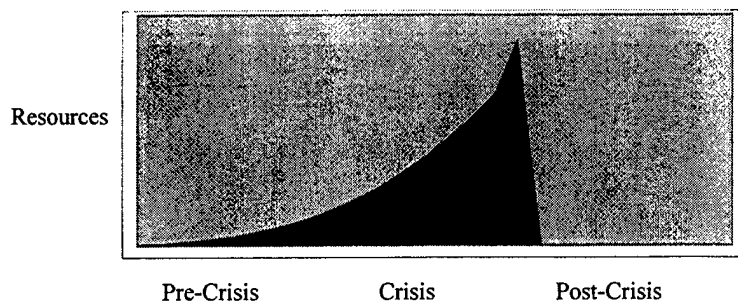
- Humanitarian responsibilities
- Political, Religious and Cultural factors
- Asymmetrical WMD challenges
- Terrorism
- Major Theater War

These multiple levels are not additive nor cumulative; they form a Multi-Dimensional Landscape.

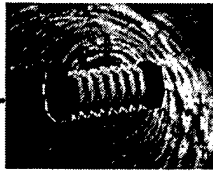


Example: Humanitarian Mission

The mission dictates the force structure, and tempo dictates structure changes



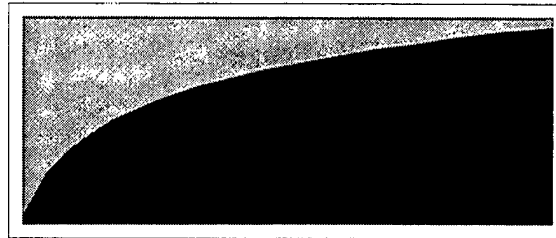
- *This scenario yields an exponential curve*



Example: Peace-keeping Mission

The mission dictates the force structure, and tempo dictates structure changes

Resources



Pre-Crisis

Crisis

Post-Crisis

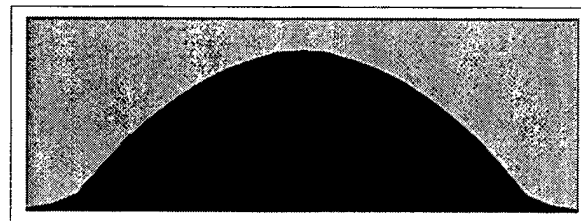
- This scenario yields a logarithmic curve



Example: Major Theater War

The mission dictates the force structure, and tempo dictates structure changes

Resources

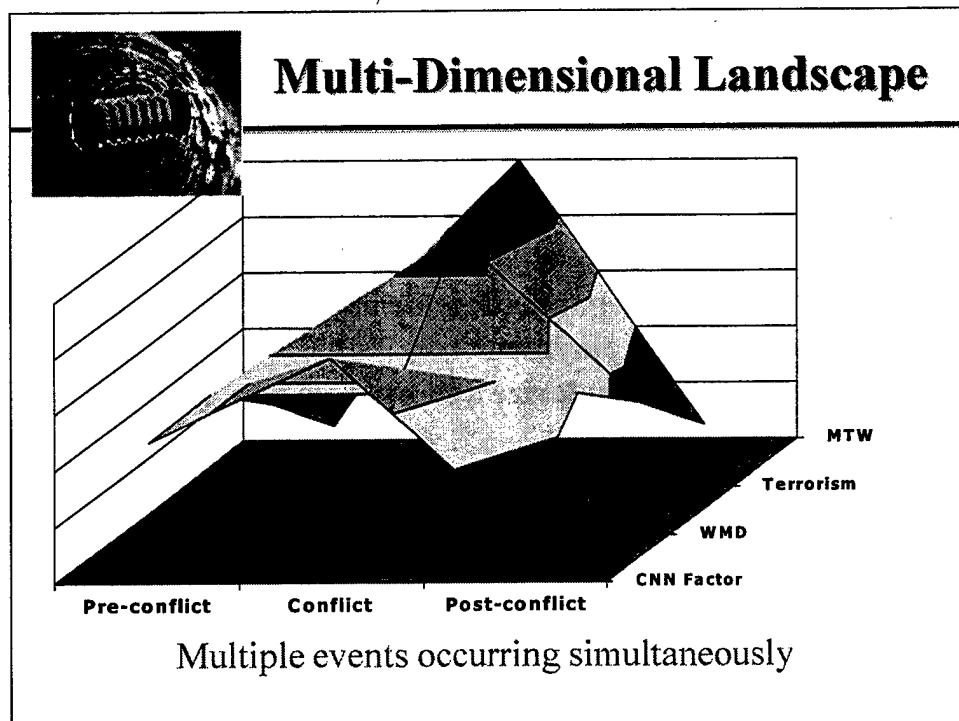
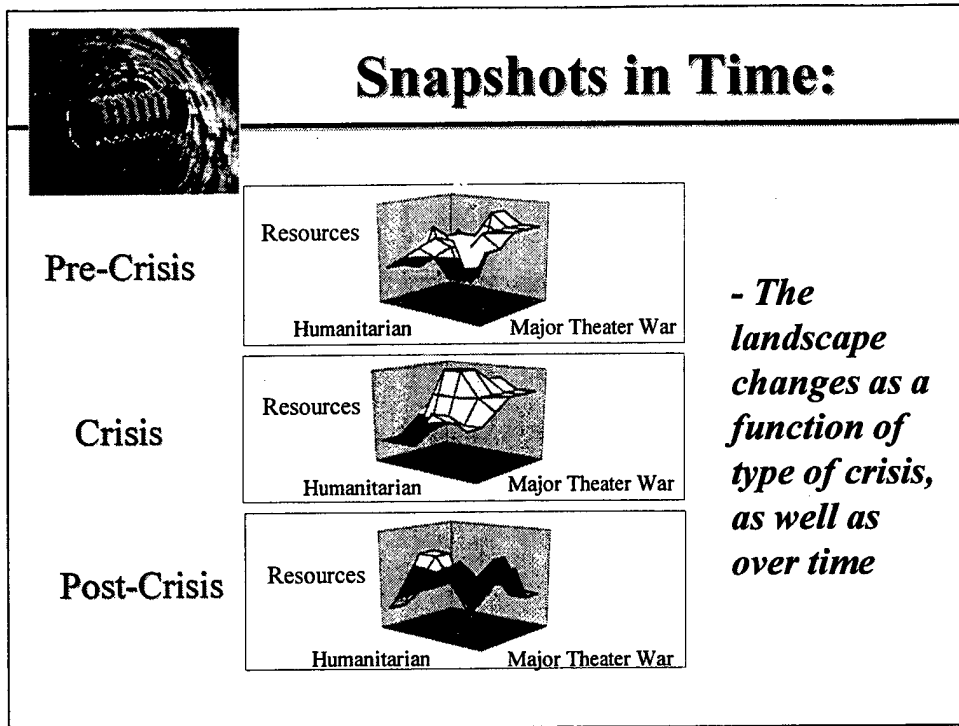


Pre-Crisis

Crisis

Post-Crisis

- This scenario yields a bell curve





Concertina Concept

Concertina:

- 1. A musical instrument resembling the accordion and differing from it chiefly in being hexagonal in shape, in having finger buttons for keys, and in having melody keys on both ends.**
- 2. An entanglement of wire usually barbed wire that can be pushed together into a compact mass for transportation and extended for use as an obstacle**

***Source: Webster's third New International Dictionary**



Concertina Concept

What is it?

- Concept of Concepts**
- Construct for organization for a JTF/CTF**
- Concept for employment**
- Concept to characterize and operate in a complex, chaotic environment**
- Concept for C2 that embraces net-centric operations**

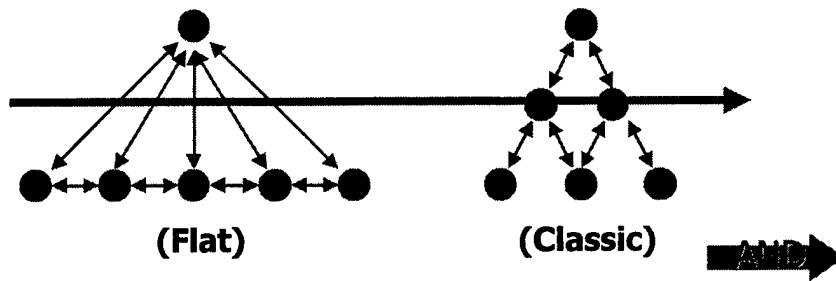


Concertina Concept

Organization/C2

Develop capabilities and technologies to enable:

- Rapid transition from a flat structure to focused vertical structure

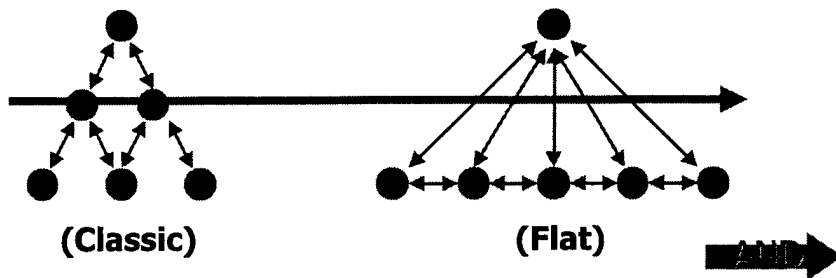


Concertina Concept

Organization/C2

Develop capabilities and technologies to enable:

- Rapid transition from a focused vertical structure to a flat structure



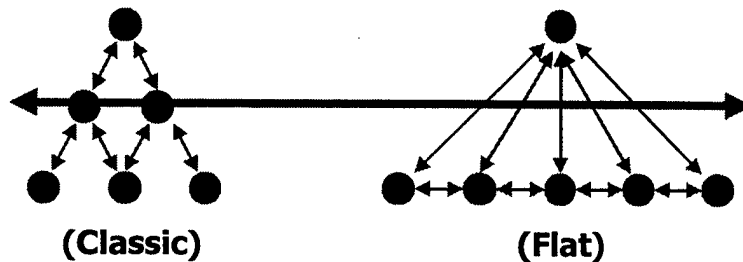


Concertina Concept

Organization/C2

Develop capabilities and technologies to enable:

- Simultaneous utilization of a focused vertical structure and a flat structure



Concertina Concept

Employment

Key Attributes

- Links CONUS based, space based, and forward deployed forces for ultimate employment by JTF
- Rheostatic range of options
- Task organized
- Combined arms
- Immediate readiness
- Expeditionary operations



Concertina Concept

Employment

Key Attributes

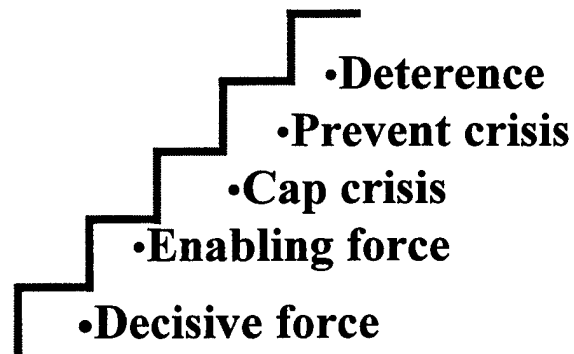
- Politically agile presence
- Flexible response available
- Tailored for the mission
- Immediately available
- Provides mission depth

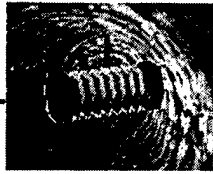


Concertina Concept

Organization/Employment

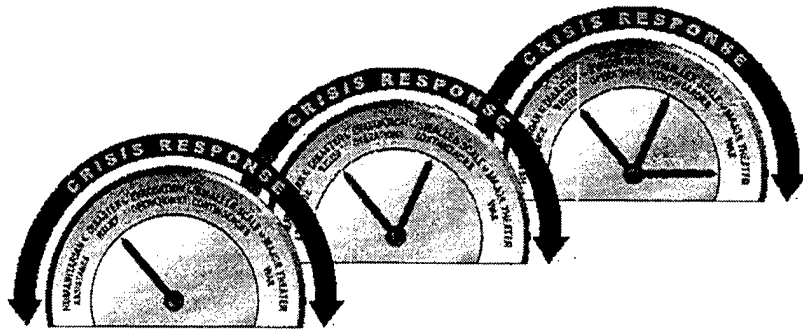
Mission Options





Concertina Concept

Rheostatic range of operations



Concertina Concept

**Lowest level composed of
functionally organized cells**

Combat cells

- Ground Forces
- Mobility
- Aviation
- Fires (shooters)



Combat



Concertina Concept

**Lowest level composed of
functionally organized cells**

Support cells

- **Combat Support**
- **Combat Service Support**
- **Joint and Interagency Support**



Combat



Support



Concertina Concept

**Lowest level composed of
functionally organized cells**

Information Exploration

- **Intelligence**
- **Surveillance**
- **Reconnaissance**



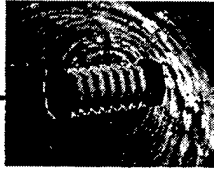
Combat



Support



IE



Concertina Concept

Lowest level composed of
functionally organized cells

C2 cells

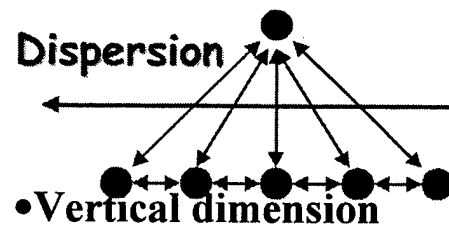
- Command
- Control

● ● ● ●
Combat Support IE C 2



Manipulate structure like a Concertina

• Horizontal dimension



Command



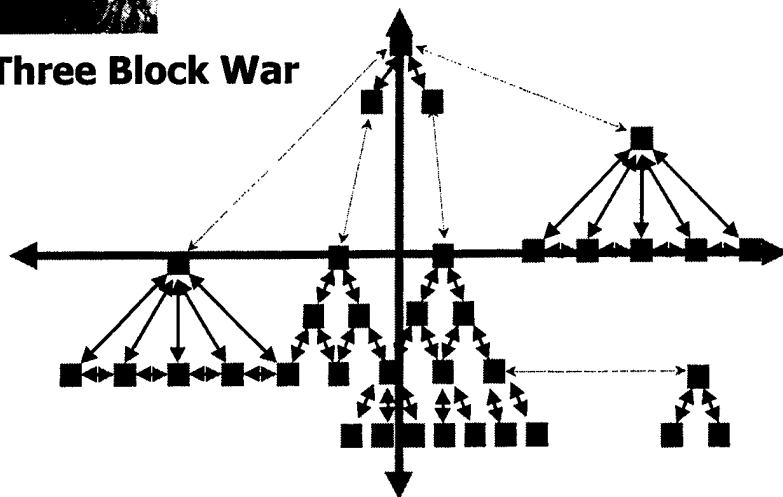
Mass

Control



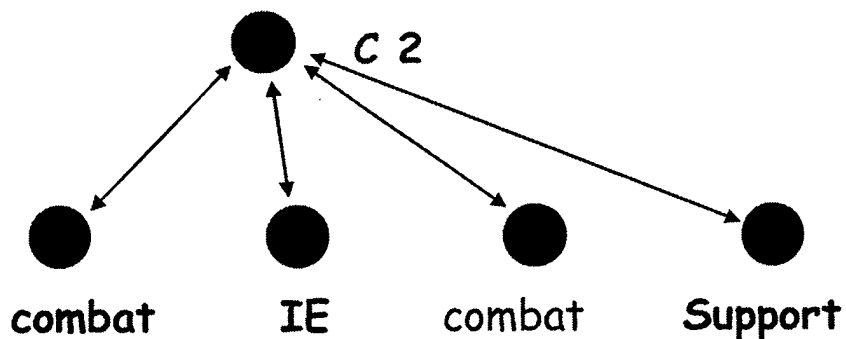
Task Organized in any configuration

Three Block War



Concertina Tiers

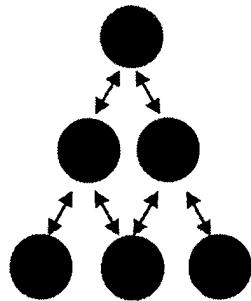
**Command can be flat to each
individual cell in the battlespace**





Concertina Tiers

Command can be expanded vertically in the battlespace



C 2

Support

IE

combat



Concertina Tiers

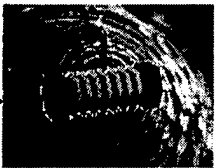
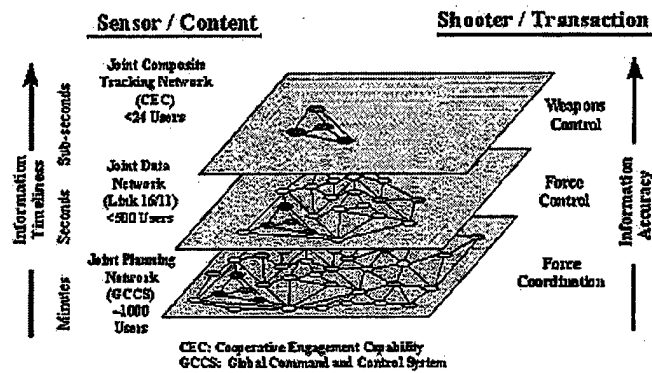
- C 2
- Support
- IE
- Combat





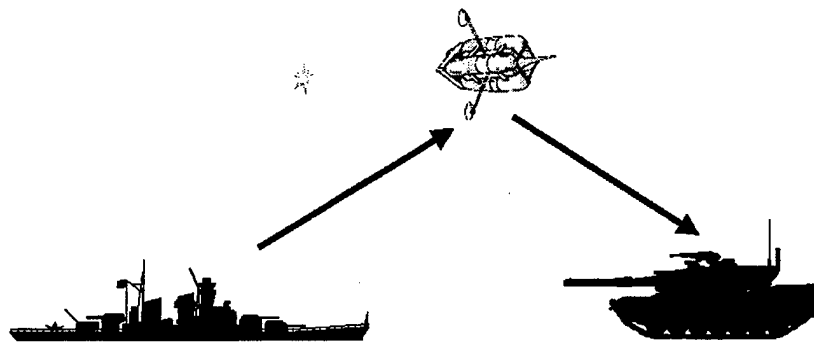
Concertina C2

Embraces network centric concept
as its backbone



Concertina C2

Embraces IT21 linkage to tactical forces





Embraces supporting ops from space





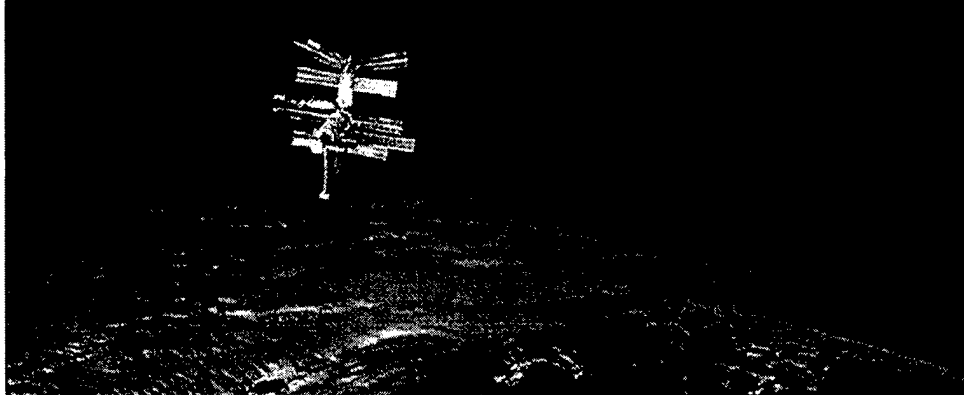
Concertina Employment

**Naval Operational Concept
Embraces forward deployed forces**



Concertina Employment

**Embraces air and space support
concepts**





Concertina Employment

Embraces Army After Next

CONUS to Theater



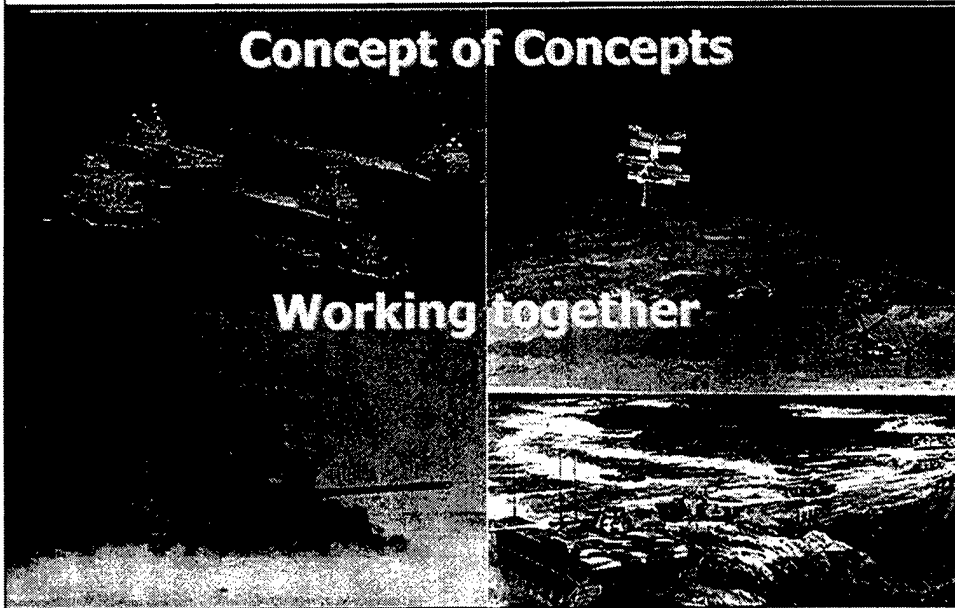
Concertina Employment

**Embraces
Operational Maneuver From The Sea**

Forward presence

Concertina Employment

Concept of Concepts



In Summary...

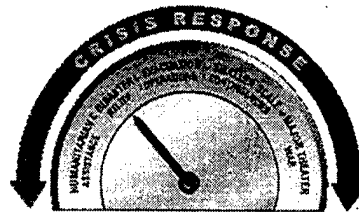
Concept of Concepts

The Concertina Concept of C² and Force Compositing is flexible and enables Joint Forces to operate on the fluid, dynamic Multi-Dimensional Landscape of 21st Century Warfare



Desired Operational Capabilities

- Real time information and knowledge sharing - Network-centric
- Ability to expand and contract the degree of control
- Extremes:
 - Lethality
 - Mobility
 - Knowledge



CHAPTER 12.

RAND Analyses – Seeking Leverage for Halting Armored Invasions: Selected Analysis and Analysis Issues

RAND ANALYSES – SEEKING LEVERAGE FOR HALTING ARMORED INVASIONS¹⁰

Selected Analysis and Analysis Issues

This section describes analytical efforts accomplished in parallel with the efforts of the study's three working groups. The study's co-leader Dr. Donald Latham had requested that RAND provide analytical support. Funding was provided by OUSD (A&T) and the Army. The intention was to use analysis to help identify where advanced technology and concepts of operations under study by the DSB could have particularly high leverage in improving U.S. capabilities for halting an armored invasion of a friendly country. The work was to draw heavily on recent or ongoing RAND research. As a member of the task force, I coordinated and assembled the materials for this volume and, during the Summer Study itself, prepared a summary of early results. That summary, "Mixes of Fires and Maneuver for Halting Invasions in Mixed Terrain: Insights from Preliminary Analysis," appears as a white paper in Volume 1 as part of the report of Working Group 3.¹¹

What follows is a set of three papers:

1. **"Exploratory Analysis of Options To Improve U.S. Early-Intervention Capability"** provides a broad view using simple analytical methods that are well suited to a system perspective
2. **"Joint Operations Superiority in the 21st Century: Analytic Support to the 1998 Defense Science Board"** describes a higher resolution, entity-level analysis of some particular issues involving the interaction of terrain, enemy movement tactics, C⁴ISR, and weapons.
3. **"Modeling, Simulation and Analysis as Critical Capabilities"**—developed during the summer study and not updated—responds to the study leadership's concern that analytical capabilities developed for past DSB studies have typically not been sustained. It describes what capabilities are needed for sustained work in both breadth and depth, notes how the current work can be regarded as prototypical in that respect, and recommends investment actions. The recommendations draw on a recent study for the National Research Council (NRC, 1997).

¹⁰ Written by Paul K. Davis

¹¹ The summary and the three papers of this section reflect discussions with fellow task-force members General David Maddox (USA, retired), Dr. Ted Gold, Brigadier General Huba Waas De Czega (USA, retired), Dr. Gene Gritton, Dr. Barry Watts, and Dr. Donald Latham. We also drew upon many discussions held in the separate working-group sessions.

EXPLORING ANALYSIS OF OPTIONS TO IMPROVE U.S. EARLY-INTERVENTION CAPABILITY¹²

OBJECTIVES

This paper¹³ uses analysis to provide insights about what types of future capabilities would be particularly valuable for “the early-halt challenge,” i.e., halting an enemy armored invasion within a matter of days. It describes a system model for analysis, shows how many of the concepts discussed in the several working groups of the 1998 DSB Summer Study can be reflected in the model, provides an exploratory analysis of the “halt problem,” and concludes with insights and observations about priorities, including priorities for further DoD research and experimentation.

OPERATIONAL CHALLENGES

In this paper, “Operational Challenges” are military problems to be focused upon in conceiving and developing new military capabilities. The challenges posed should be important in their own right for addressing near- and mid-term difficulties; they should also be “forcing functions” for progress in the effort to “transform the force” as called for in the Quadrennial Defense Review (Cohen, 1997) and described in broad terms in *Joint Vision 2010*. The Secretary of Defense has embraced the idea of operational challenges and, in the Defense Planning Guidance, has directed work on early interdiction of an armed invasion force (the “early-halt challenge”). The 1998 DSB study considered a number of challenges, but ultimately focused much of its effort on the early-halt problem.

ASSESSING POTENTIAL CAPABILITIES IN A “SCENARIO SPACE”

Consistent with a desire for robust, flexible, and adaptive capabilities, our analysis in this paper assesses the potential value of capabilities for a wide range of scenarios and scenario details. That is, it assesses capabilities for a large *scenario space*. In evaluating capabilities we consider not just standard planning scenarios, which assume considerable warning, reliable allies, and purely conventional conflict, but also more stressful scenarios. In particular, to reflect effects of uncertainty we considered the effects of

- So-called “asymmetric strategies” such as chemical attacks on ports and bases, which would strike at current U.S. Achilles’ heels

¹² Written by James Bigelow, Paul K. Davis, and Jimmie McEver

¹³ This RAND paper, prepared in support of the DSB summer study, has not been formally reviewed or edited. It draws heavily on an ongoing cross-cutting project for the oversight board of RAND’s National Defense Research Institute (NDRI), a federally funded research and development center (FFRDC) that serves the Office of the Secretary of Defense, Joint Staff, defense agencies, and unified commands. See Davis et al. (1996), Davis, et al. (1998a), and Davis et al. (forthcoming) as cited in the bibliography. The latter two papers elaborate on the use of operational challenges to drive transformation.

- Smart invasion strategies involving multiple axes of advance, force dispersal, clever use of air defenses, and unpredictable maneuver times
- Imperfect command and control

Not all uncertainties work to the U.S. disadvantage, however. We also examined the upside potential of capability options in favorable cases with

- Enemy forces of modest size and with relatively low morale and competence

In all of this work, we sought not to reach definitive conclusions, but rather to clarify what is feasible (as a function of circumstance), to identify capabilities that would be of particular value across the scenario space, and to highlight areas of ignorance where more research and analysis is needed. **Although the analysis we present here made many assumptions about scenario and other factors, the emphasis is on broad insights rather than conclusions sensitively dependent on those assumptions.** Our effort was limited, of course, by both time and resources.

ANALYSIS IN DEPTH AS WELL AS BREADTH

This paper stresses analysis in breadth (addressing many cases), but in-depth analysis is also important and we identified several topics on which it is especially so. We then conducted our DSB work in parallel with focused entity-level gaming and simulation by colleagues (Matsumura, Steeb, et al., 1998). This was especially important in understanding underlying phenomena and the interaction of tactical measures and countermeasures, weapons, C⁴ISR, and terrain. It also helped us establish reasonable uncertainty ranges for aggregate parameters such as kills per sortie or shot, as a function of circumstances, although we were able only to scratch the surface in this regard. More generally, work should exploit special multiresolution models and families of models (NRC, 1997 and Davis and Bigelow, 1998).

TAKING A SYSTEM APPROACH

Finally, even in a limited analysis such as this, we considered it imperative to take a *system approach* that would clarify how achieving the capability to halt an invading army quickly would depend on a whole *set* of operational capabilities. This is significant because a common tendency in force planning is to place a great deal of emphasis on one or another capability thought to have high leverage when, in fact, the ultimate leverage will also depend strongly on improvements of other system capabilities.

One way to operationalize the system perspective is to decompose the early-halt challenge into subordinate challenges, which themselves decompose. As Figure 1 indicates, an early halt is likely to require that the United States quickly establish theater-wide air and missile defense, and theater-wide command and control. It may require the quick securing of air bases, ports, and sea lanes. Except in unusual cases, it will require rapid deployment of forces. And, finally, it will require effective employment of effective forces.

As shown along the bottom of Figure 1, the U.S. will probably need a number of crosscutting capabilities important or necessary for each of the subordinate challenges. These include

network-centric command and control (Cebrowski and Garsktak, 1998), long-range fires (aircraft and missiles), and so on as indicated.

The point, again, is that accomplishing a quick halt is not simply a matter of having enough aircraft, ships, and ground forces. To the contrary, success requires success of a complicated operational-level *system* expected to work with a smoothness unprecedented in quick-response defensive actions.

In this paper we focus largely on the branch indicated in Figure 1, the branch concerned with effective force employment of long-range fires. However, we consider other branches implicitly by our choice of cases and parameter values. See Matsumura, Steeb, et al (1998) for discussion of how ground-maneuver forces might be used early as part of the early halt.

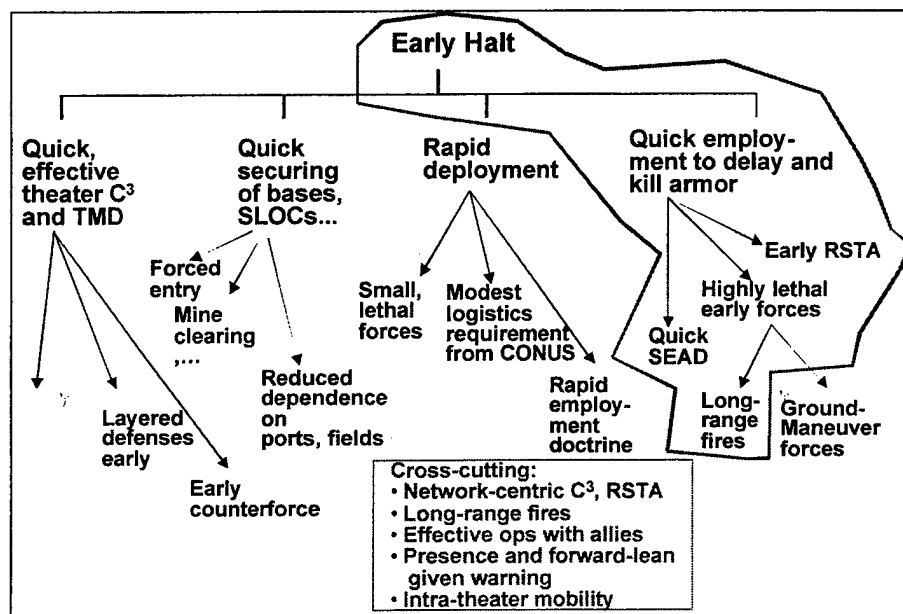


Figure 1—Decomposing the Early-Halt Challenge

A SIMPLE MODEL FOR ANALYSIS

In the problem we consider, a joint and combined force must intercept, halt, and to some extent destroy an invading force quickly. The invasion involves a Red armored column whose objectives are typically hundreds of kilometers from its borders. The prototype is an invasion of Kuwait and Saudi Arabia by Iraqi forces. The challenge is to halt the column relatively far forward by means of long-range strikes by aircraft and missiles only,¹⁴ except to the extent that available ground forces can slow the enemy advance and provide improved targeting information. If the long-range fires cannot by themselves stop the advance, the intention is that they at least greatly reduce the size and coherence of the enemy force reaching defensible

¹⁴ For a first version of such work, see Davis and Carrillo (1997). See also Ochmanek, Harshberger, Thaler, and Kent (1998), which documents a substantial fires-oriented analysis largely completed in 1997.

positions such as northeastern Saudi Arabia, where U.S. forces might gather.¹⁵ The results of all such studies should be viewed more as measuring the potential value of alternative fires and maneuver forces than as representing events in a real-world operation.

We constructed a relatively simple multiresolution model family for the early-halt operational challenge. Figure 2 shows the highest-level logic of our model. Each day of the campaign, Blue has some numbers and types of shooters (our generic term in this model for aircraft, helicopters, and missiles) in the theater, whether the result of having been forward deployed in peacetime, moved into the theater upon warning, or deployed during the campaign itself. These shooters are assigned by Blue C² to attack the column. Meanwhile, the Red column advances towards its objective. The contest becomes a race: can Blue kill enough armored fighting vehicles (AFVs) at time T_{halt} before the remaining Red vehicles reach their objective, or before Red has penetrated beyond Blue's intended defense line?

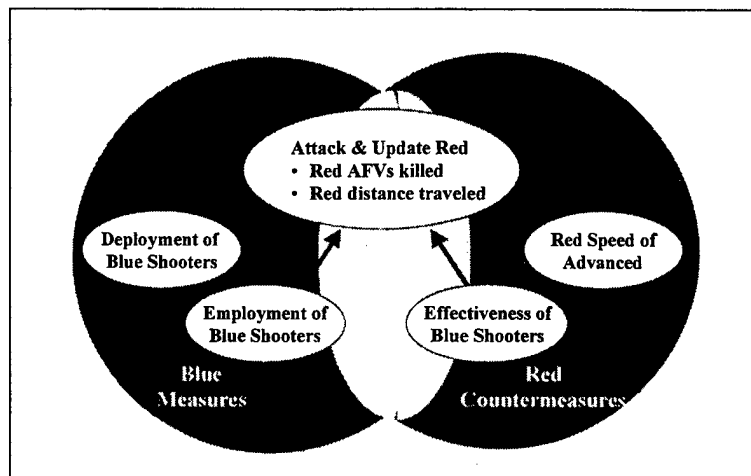


Figure 2—Top-Level View of Model

As Figure 2 suggests, these steps take place on a background of Blue measures and Red countermeasures. Blue must have shooters in the theater, but Red can use chemical attacks to deny Blue the use of some airbases. Blue must fly anti-armor missions to win, but Red air defenses can make those missions costly.¹⁶ In turn, Blue can counter Red's air defenses by attacking them, or using stealthy or standoff weapons. Blue must locate Red targets, but Red can hide his vehicles, use decoys, or disperse his vehicles.

In the next several figures we expand on each of the steps shown here and identify the "hooks" in our analysis for DSB-postulated concepts and capabilities.

¹⁵ A theater-campaign model dealing with mobility and with joint and combined warfighting (including close battle) is needed for more comprehensive analysis. For analysis with relatively rich scenarios creating access problems caused by both political problems and chemical attacks, see Davis et al. (1998b).

¹⁶ Blue can tolerate some losses, but we assume the campaign will be managed so as to keep losses at low levels. The simplest version of the model ignores losses, but will not fly non-stealthy aircraft against the Red column while Red's air defenses are active.

AVAILABLE SHOOTERS

The number of shooters in the theater is determined (Figure 3) by the number that are stationed in the theater initially, warning times,¹⁷ and the arrival rate. In addition, there may be limits to how many shooters can deploy to the theater, both because we can only dedicate a limited number to a given theater, and because available airfields have limited capacities.

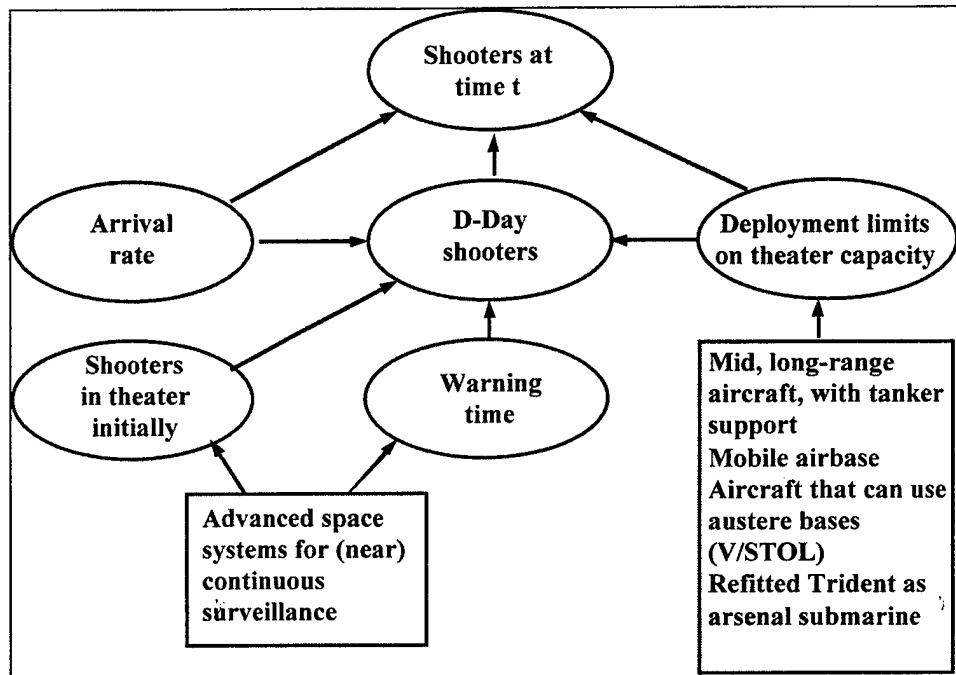


Figure 3—Factors Affecting Number of Shooters

All of these quantities are "hooks" for Blue measures and Red countermeasures. In Figure 3 and subsequent figures, we show illustrative improvements (most of them discussed explicitly by DSB working groups during the summer study) in rectangles attached to the model parameters that can represent their effects.

For example, Blue can increase the theater capacity: first, by employing long-range aircraft with suitable tanker support, thereby making use of more bases, and, second, by deploying weapon systems capable of using relatively primitive bases (e.g., V/STOL aircraft). Red may try to deny Blue the use of the most forward and best-equipped airbases, at least temporarily, by means of chemical or biological attacks. Blue can avoid the effects of these attacks by relying increasingly on long-range aircraft, deploying more tactical aircraft on aircraft carriers or a possible mobile airbase, or by deploying more missiles on ships. In turn Red can partially counter these measures by mining the sea approaches (if any), forcing operations to longer range and reducing missile payloads. In time (2010?), Red could threaten surface ships with large numbers of cruise and ballistic missiles supported by surveillance craft. Defense might be quite

¹⁷ The model considers two warning times. After strategic warning Blue can make certain preparations, such as directing a carrier battle group to steam towards the theater, and putting units on alert. But only after tactical warning can full-scale deployment begin.

difficult because of the leakage problem. However, a converted Trident submarine (an “arsenal submarine”) would be survivable.¹⁸

Blue, of course, can hope to increase warning time by observing continuously, from space or aerial platforms, for signs of a Red intention to invade. Red can act to conceal intentions, at least by making them ambiguous.

Employment of Blue Shooters

As Figure 4 suggests, not every Blue shooter in the theater will fly missions against Red’s AFVs during each time period. Some fraction of shooters will be allocated to other missions, such as attacking strategic communication nodes, missiles, and WMD installations. Others will suppress air defenses (the SEAD mission) early in the campaign. Those shooters that cannot fly SEAD missions but are vulnerable to Red’s air defenses will have to wait until SEAD is accomplished. Most current heavy bombers (e.g., B-1B, B-52s) fall in this category, as do F-15s and F-18s. B-2Bs are usually thought of as more appropriate for strategic bombing, but future stealthy heavy bombers could, of course, be used early for interdiction.

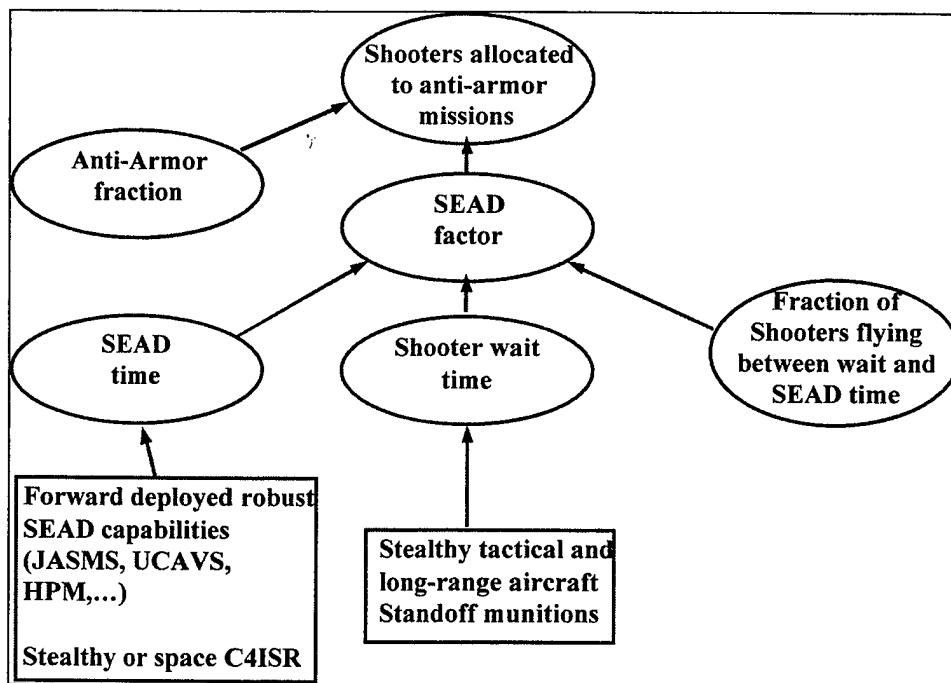


Figure 4—Factors Affecting Employment of Blue Shooters

The SEAD factor captures the effect that enemy air defenses (e.g., SA-10s and mobile SA-12s) could have on preventing many Blue shooters from flying sorties.¹⁹ Stealthy aircraft and

¹⁸ Submarine options were discussed in the abstract in the 1996 DSB study led by John Foster, but relatively well defined options were discussed in the current study as the result of recent studies by the Navy in recognition that some Tridents will soon be retired if they are not reconfigured for non-nuclear missions.

missiles can strike before Red's defenses are suppressed, but helicopters and non-stealthy aircraft cannot. Unfortunately, Blue may not be able to "enforce" a best-estimate SEAD time, because Red could withhold some of his air defenses until the end of the period Blue thought would be necessary. Blue can reduce the SEAD time by deploying systems that are better at locating Red's air defense assets, and are themselves less vulnerable to them (e.g., unmanned combat aerial vehicles (UCAVs), high-power-microwave weapons (HPM), and large numbers of standoff missiles).

EFFECTIVENESS OF BLUE SHOOTERS

Overview

Continuing with the items of Figure 2, the next issue is the effectiveness of available Blue shooters. Figure 5 shows how we modeled that effectiveness as a number of factors. Let us first consider what constitutes the "nominal" effectiveness levels.

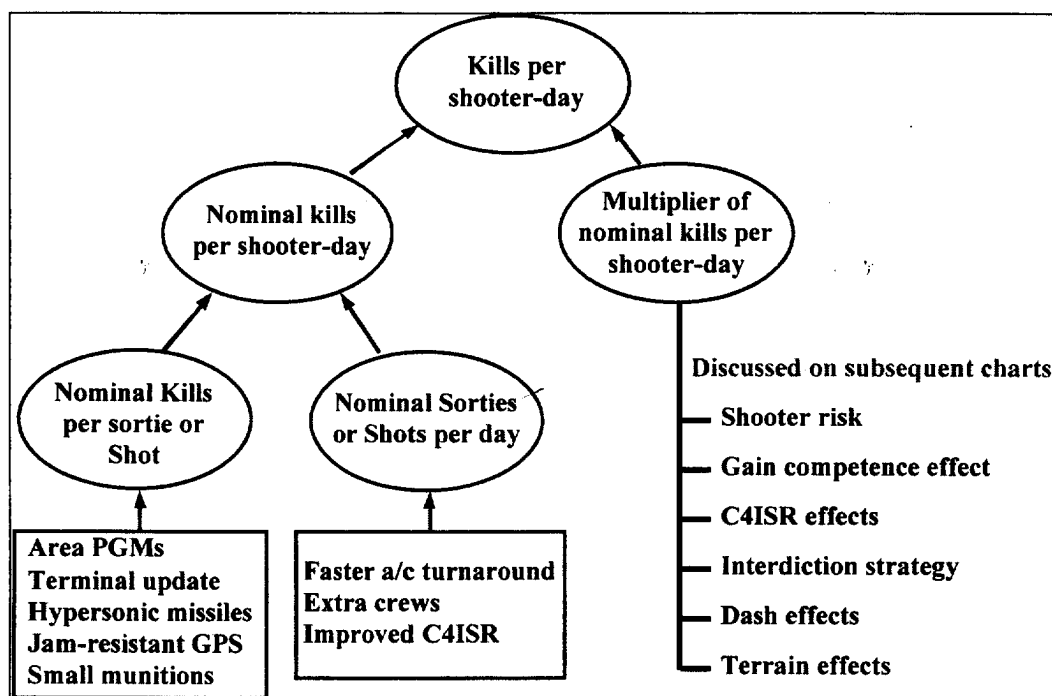


Figure 5—Factors Affecting Effectiveness of Blue Shooters

Blue shooters (aircraft or missiles) kill Red AFVs by a multi-step process:

- The C⁴ISR system identifies a general area where targets may be found.
- Aircraft sorties are directed or missiles fired.

¹⁹ We have in mind future adversaries with more and much better SAMs than Iraq currently has. Such improved SAMs are already available on the world market and will only become more effective with time.

- Target vehicles or groups of vehicles are pinpointed, either by the shooters themselves or by other means (e.g., J-STARS or UAVs)
- Aircraft fire anti-armor munitions or missiles dispense submunitions over the target.

Either step 1 or 2 can limit the number of sorties or shots per shooter-day. Thus, if Blue's C⁴ISR system cannot project areas that will contain targets by the time weapons arrive, Blue will not use all the sorties his aircraft are capable of flying, and will withhold his missiles. Conversely, if Blue locates ample targets, he may generate as many aircraft sorties as possible, fire all his missiles, and wish for more. Blue cannot fire a missile more than once, but he can develop methods for generating more sorties by aircraft. If step 1 is limiting, better C⁴ISR will find more targets and thus allow more sorties. If step 2 is limiting, extra crews (both ground and air) may speed aircraft turnaround. As mentioned earlier, Red can reduce sorties by Blue ground-based aircraft by chemical and biological attacks on airbases, forcing Blue to operate from more distant and typically more austere bases (perhaps not so if the U.S. developed a mobile-airbase platform).

Similarly, either step 3 or 4 can limit the kills per sortie or shot. The maximum number of times an aircraft can execute step 4 during a single sortie depends on the number of munitions carried by the aircraft and the doctrine for allocating them to targets. Increasing the load (e.g., by substituting an aircraft that carries a larger load or, more likely, by using the types of advanced, small, lethal munitions discussed in the summer study) may increase the kills per sortie, as can increasing the weapon footprint. For example, tactical aircraft could use the BAT munition, which has a much larger footprint than sensor-fused weapons (SFWs), but at a much higher price. Or, by creating and exploiting bottlenecks, Blue would be able to deal with more congested targets, although discriminating between live and dead targets would become increasingly important. Further improvements to the munition's accuracy and reliability are also possible. Weapon accuracy for tactical aircraft can be improved, for example, by a combination of wind corrections, GPS guidance, terminal updates, faster missiles, and countermeasures to GPS jamming.

A missile can also engage multiple targets, if they are not dispersed too widely. Blue may increase the number of kills per shot by increasing the number of submunitions each missile carries or the area over which they are lethal. The value of increasing footprint, however, depends on details of terrain and other factors.

There are many possible Red countermeasures, which include hiding, jamming, dispersing, and decoys. See DSB, 1996b for a speculative discussion and Matsumura and Steeb (1998) for analysis that includes effects of movement tactics.

In the next sections, we discuss a number of other things Blue and Red can do to influence Blue's effectiveness. These are depicted in Figures 6 and 7.

Effects of Shooter Risk-Taking

Blue pilots can fly sorties in different ways and can take risks to increase their effectiveness (left side of Figure 6). For example, they can fly lower and fire their anti-armor weapons from close range, or fly higher and fire from longer range. Both kills of Red vehicles and losses of Blue shooters could be larger in the first instance than in the second, though the effect would be unimportant for standoff weapons with sufficient range and endgame targeting. But the risk associated with a particular type of sortie will also depend on the state of Red's air defenses. We have assumed that Blue manages the campaign so as to limit his losses to negligible levels.

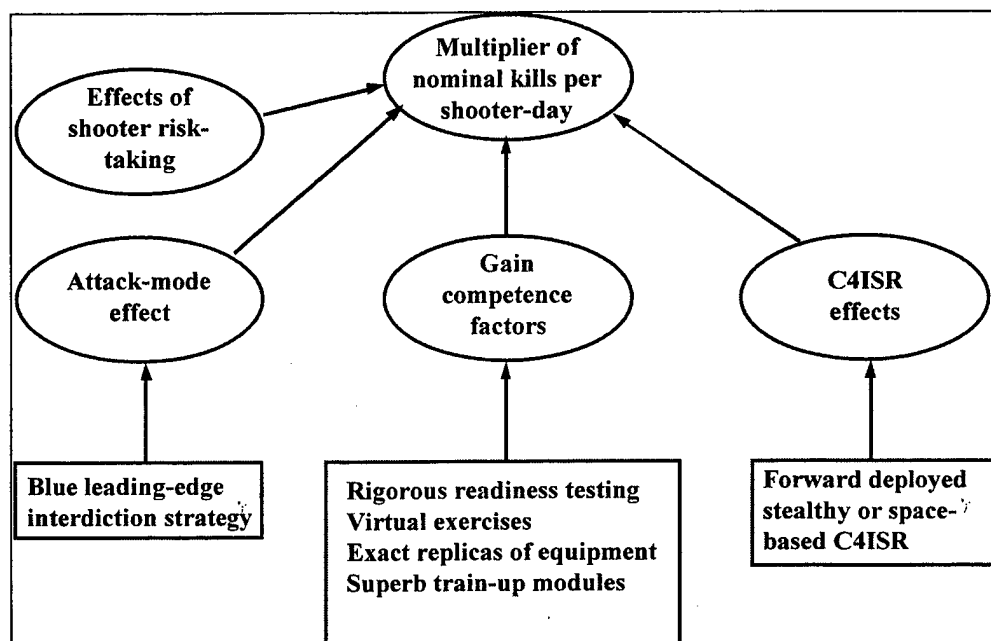


Figure 6—Correction Factors Affecting Effectiveness

Effect of Interdiction Strategy

Blue's interdiction strategy matters also (left side of Figure 6). Our model allows two types of Blue interdiction strategy. In one, Blue attacks all parts of the column equally. In the other, Blue concentrates his attack on the leading elements. This leaves the density of vehicles unchanged but shortens the column by lopping off the front. Attacking the lead elements²⁰ influences Blue effectiveness by two mechanisms. First, effectiveness may be reduced by deconflation and survivability problems flying a large number of sorties in a confined area. On the other hand, crews of vehicles near the front of the column may panic due to the high percentage of vehicles being destroyed in their immediate vicinity. The model counts a vehicle whose crew abandons it in panic as incapacitated, as much lost to Red as a destroyed vehicle. Most important, shortening the column from the front reduces the effective rate of advance. For

²⁰ This treatment reflects in one model alternative force-employment strategies. The leading-edge attack was suggested by colleague Glenn Kent and first described in Ochmanek et al. (1998) in work for the Air Force. It is particularly effective only when the number of advancing columns is small and the attackers are road-bound. In other circumstances, the attack-in-depth strategy (Davis and Carrillo, 1997) can be superior.

example, if 160 of the 1600 vehicles in each column are taken at random from the column, the front still advances 80 km each day. If the same 160 vehicles are taken from the front of the column, the front advances in the model by only 64 km/day. Red could counter this tactic of Blue's by advancing along multiple axes with multiple columns per axis. Current threats, however, are not obviously capable of significant off-road movement, so the leading-edge strategy is potentially attractive.

C⁴ISR EFFECTS AND GAINING COMPETENCE

We consider a number of effects of improving the Blue C⁴ISR system (middle and right of Figure 6). Current sensor platforms are vulnerable to air defenses, so we degrade Blue effectiveness (measured by kills per shooter-day) by a factor that decreases with time until SEAD is complete. Our 'Base' C⁴ISR system is degraded most, an 'Enhanced' system is degraded less, and a 'High End' system is not degraded at all. The base C⁴ISR system might depend on something like a J-STARS, which would be highly vulnerable to long-range SAMS. The high-end system should have stealthy sensors and jam-proof communications.²¹ Once SEAD is completed, each system rises to a different long-term effectiveness, with the base system lowest, the high-end system highest, and the enhanced system in between. The parameter values we have chosen to describe these three systems are merely illustrative pending calibration to more detailed studies, but they reflect qualitatively what might be expected. They also provide a hook for data from joint experiments that could and should be done at USACOM.

The model also assumes there is a learning period for C⁴ISR, a time to gain competence. This multiplier of effectiveness starts at a low level when strategic warning is first received, and rises towards one. Thus, the longer the strategic warning time, the less the gain-competence effect. This effect represents the time it may take to place C⁴ISR assets in the theater, and establish the C³ network. We added this effect (Davis, et al., 1998b), which we have not seen previously in studies, because it seemed likely to us that real-world command and control effectiveness would be a good deal less initially in a campaign—especially if operators had not previously worked together with actual displays and procedures. There are also limits on the traffic-handling capability of individual platforms such as J-STARS.

Effects of Enemy Dash Tactics

Red will probably not simply march across the terrain at a uniform pace as assumed in most halt models. Instead (Figure 7), he may concentrate his maneuver in time so as to reduce the exposure of his forces, "dashing" forward for two or three hours, and then going into hiding (much more feasible in mixed terrain than in the desert). Then many of Blue's sorties might arrive when the army is in hiding and his aircraft will be less able to find and attack the hidden Red vehicles. To counter this postulated tactic, Blue must either be able to locate the stationary, hidden Red vehicles, or respond very quickly when Red vehicles are observed during their dashes. Good network-centric operations would help. For example, when moving targets

²¹ It was beyond the scope of this work to assess whether advanced hovering stealthy UAVs for C⁴ISR will be survivable in the presence of long-range SAMS. If they must radiate, then that will obviously be a vulnerability, which Stealth can only partially overcome.

“disappear” from a J-STARS display, that could provide information on where targets may be hiding. Foliage penetrating radar (FOLPEN) could then be focused on the appropriate areas.

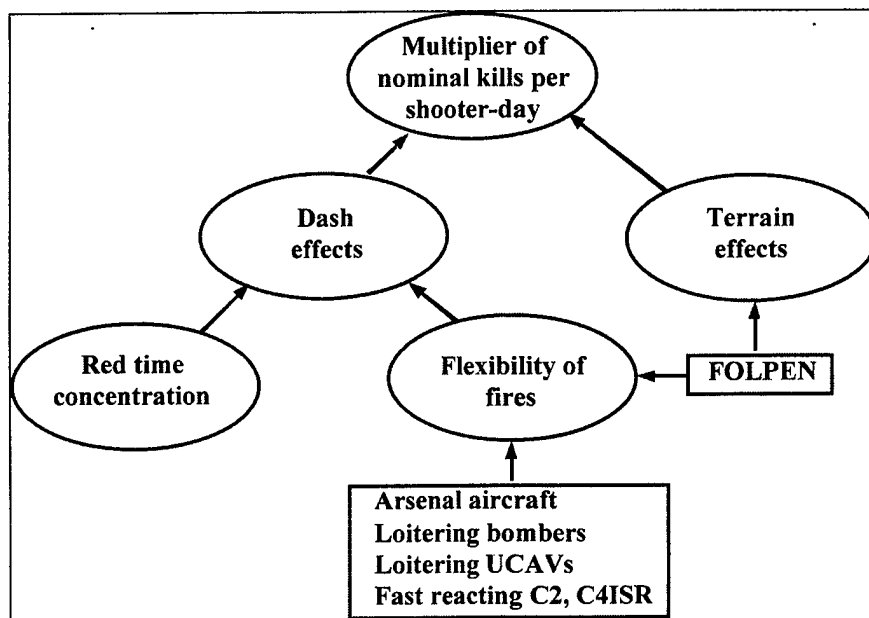


Figure 7—Effects of Dash Tactics and Terrain on Force Effectiveness

If Blue must be effective during temporary “dash periods,” then very good command and control, coupled with either very fast missiles or with aircraft or UCAVs that could loiter in the target area, might be called for. Putting aircraft on strip alert, and maintaining CAP stations, would also be possible. In contrast, a traditional air-tasking-order approach that schedules detailed missions a day in advance would not have this flexibility.

We saw an effect in some ways similar to the dash effect in the high-resolution simulation experiments reported in Matsumura, Steeb, et al (1998). There the Red armored forces were traveling over mixed terrain, a considerable fraction of which was covered by a foliage canopy. A cluster of Red vehicles could be detected by the C⁴ISR system, and a missile launched so as to hit the vehicles in the next open area, which depended on ability to predict their arrival. But predictions were difficult and grew worse with increased time of flight from last reliable update (e.g., 15 minutes in base cases). The simulations showed a factor of three reduction in the effectiveness of long-range fires due to mixed terrain. Red’s assumed dispersal tactics reduced effectiveness considerably more.

In previous work (DSB, 1996 or Matsumura, Steeb, et al., 1997)) it became clear that *either* loitering weapons *or* the ability to update the targeting of en route platforms *or* large-footprint weapons would be quite valuable because of the difficulty predicting future target locations. The current work shows, however, that the updating option might not suffice. Even if the platform or missile could be updated en route, the necessary information might not be available because the targets would be in foliage. Foliage-penetration radars (FOLPEN) are therefore desirable.

Slowing the Enemy Advance

If we now refer back to the top-level view of this system (Figure 2), our next variable is Red's movement speed. Historically, military forces of division size and larger have traveled less than (sometimes much less than) 100 kilometers per day. Companies and platoons typically travel faster, and individual vehicles can travel many hundreds of kilometers per day. But large units are slow for complex reasons involving command and control, logistics, road capacity, and the need to build enough slack into movement plans to allow for inevitable problems—whether due to nature, the opponent, or the army's own snafus. One important issue (Figure 8) is how to slow the movement enough for fires to take their toll before the enemy gets very far.

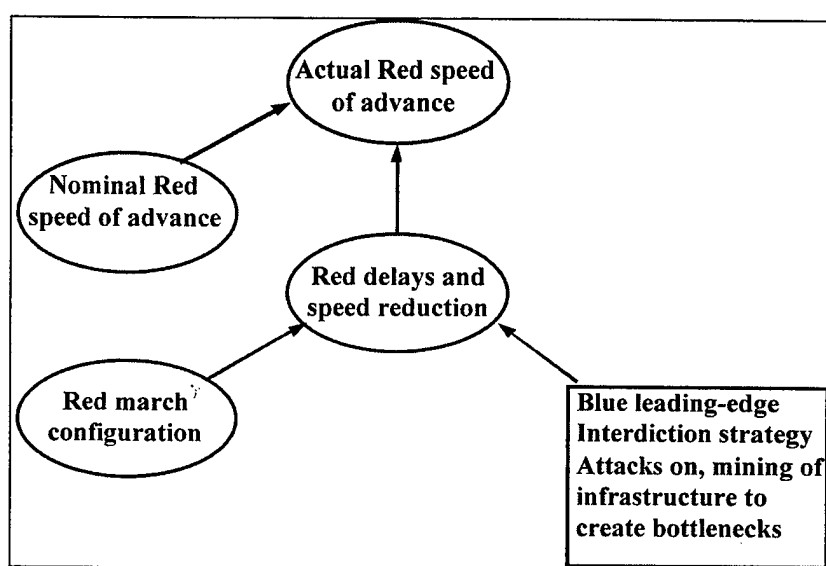


Figure 8—Slowing Red's Rate of Advance

Red's speed of advance depends on Blue's interdiction strategy as described earlier, and on Red's march configuration (number of axes and columns of advance). If Blue concentrates his attacks on the leading elements, the distance of advance is reduced by the amount of column destroyed per day. Blue may also affect Red's speed of advance by attacking critical infrastructure elements such as bridges and roads, though such attacks will only delay Red if alternative routes are significantly longer, or require substantial backtracking, or if the attack reduces the infrastructure's capacity to carry military units.

Red tactics may have the side effect of preventing Blue from slowing Red. Red's air defenses, for example, may prevent Blue from effectively attacking Red for some days at the start of the campaign. During this time, Red may be able to travel steadily, at a relatively rapid pace. Later, once his air defenses have been suppressed, Red may have to depend more on dash tactics and parallel axes of advance. It is likely that his speed will decline.

Nature also plays a role in determining Red's speed. Red may travel more rapidly over open, flat terrain than over steep, broken terrain. Inclement weather will slow him down, as will the

need to cross rivers and other barriers. In a fuller treatment, we would have explicitly modeled obstacle creation with mines, bombing, and ambushing, including importantly actions taken by our defended ally (perhaps in special operations with U.S. assistance).

A FIRST BROAD EXPLORATORY ANALYSIS

NATURE OF EXPLORATORY ANALYSIS

Having described a model of the halt phase, in what follows we describe an “exploratory analysis” of the halt campaign. This differs from the more traditional sensitivity analysis in several ways. First, it considers the effects of large changes in variables, where the traditional analysis typically defines a base case and explores relatively minor excursions from it. Second, it considers changing all the variables, not just those under Blue’s control. The typical analysis assumes a game board and Red behavior, and then designs a Blue force to meet that fixed situation. Third, exploratory analysis considers results of changing all the variables *simultaneously*, not just one-by-one.²²

Traditional analysis assumes more knowledge of the situation than anyone can possibly have. At present, we don’t know where we will fight a halt campaign, or against whom, or what they or we will have done to develop weapons or tactics in the meantime. We have an abundance of uncertainty and ignorance, and it behooves us to examine a wide range of possible campaigns rather than defining only one or two as a design point for our future forces. This is indeed essential if we seek robust, flexible, and adaptive forces (Davis et al., 1996).

A traditional analysis also tends to pick cases that are hard for Blue. This makes sense if one can only examine one or two cases. But since we can examine multitudes of cases, we can pick some that are easier. Blue can choose which halt campaigns to try to win, and if some are too hard, it may be best to back off and rely upon longer-term instruments. Looking at both hard and easy cases may help one pick the level of difficulty to design for.

Even though the model outlined above is simple by comparison with typical combat simulation models, it is nevertheless too complicated to use as is for exploratory analysis. Depending on how one counts, it uses scores or even hundreds of parameters to describe the deployment, employment, and effectiveness of multiple types of Blue shooters over the duration of the campaign (up to 30 days). To make exploratory analysis practical, we must restrict the number of parameters we vary. Computational considerations matter here, but even more fundamental is the fact that trying to make sense of thousands or millions of cases—each described by hundreds of parameters, would be more confusing than enlightening. Further, in practice decision makers must “think” in terms of abstractions (aggregate variables).²³

²² Analysts have long known of the desirability of such simultaneous variation and some early descriptions of sensitivity analysis noted it. In practice, however, “sensitivity analysis” has become almost synonymous with one-variable-at-a-time testing around one or two pivot points.

²³ The fundamental need for aggregate-level analysis is discussed in some detail in Davis and Bigelow (1998) and, in lesser detail, in NRC (1997).

SIMPLIFYING THE HALT MODEL FOR INITIAL EXPLORATION

To simplify the model sensibly, let us first review the complete model, which Figure 9 shows as a hierarchy of variables—referring back to Figures 3-8 for elaboration of modules. This hierarchical construction allows us to examine issues at different levels of resolution (Davis and Bigelow, 1998). For the purposes of this paper, detailed and aggregate versions of the model differ only in the shaded regions. To construct the aggregate version (Figure 10), we replaced the shaded portions of the hierarchy with simpler structures that can be described by only five parameters, which are shown in Table 1.

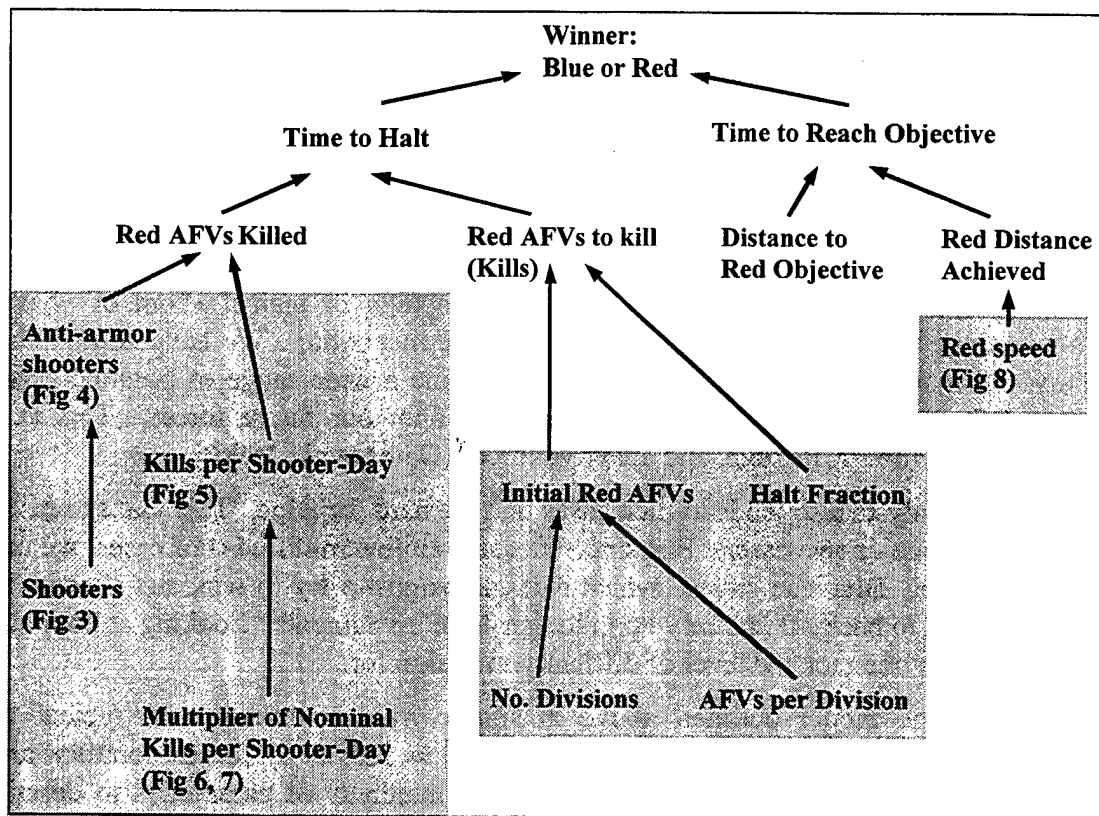


Figure 9—Structure of the Halt Model

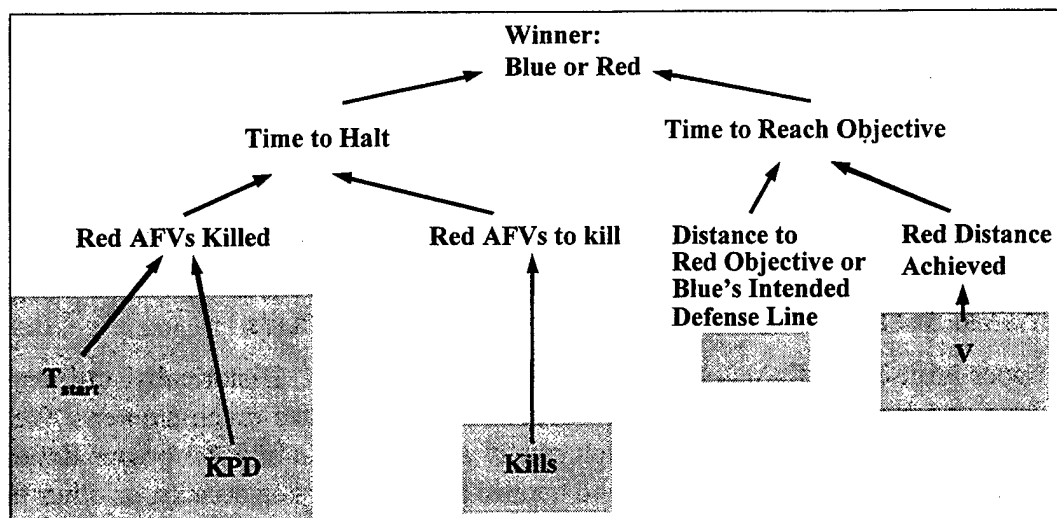


Figure 10—Structure of the Simplified, Aggregate Halt Model

We settled on the five parameters shown in Table 1 following some experimentation with more complex aggregate representations. We did not find that the additional parameters we tried improved our understanding of the halt problem and what it would take to solve it. Thus, while this is ruthless reductionism, it seemed warranted in our broad look.

Table 1: Aggregate Input Parameters And Their Ranges

Name	Description	Minimum	Maximum
Kills	Red AFVs to kill	500	4000
	Distance Red penetrates (km)	100	300
D	Rate of advance of the Red column (km/day)	20	100
V	Start time of anti-armor missions (days after start of war on D-Day)	0	8
T_{start}	Kills per day (by all shooters)	100	1000
KPD			

These five parameters are related to the scores or hundreds of variables in the more detailed version of the halt model. An analyst represents concrete policy measures (e.g., a new munition, improved C⁴ISR) in the detailed model by changing one or more of those many variables. Because there is an explicit mapping between these five aggregate parameters and the more numerous variables in the more detailed model, we have a systematic way of linking concrete policy measures to the five parameters. The analysis strategy, then, is to identify which of the

five parameters drive success in the halt problem, and then re-express those parameters in terms of the dozens of more detailed variables. Then we can determine which of them have the greatest value for halting a Red armored column by long-range fires.

We restrict our attention to ranges of these variables that we consider interesting. The largest interesting value of Kills is limited to the number owned by the strongest military power we could face. Moreover, we needn't plan for our military to annihilate this largest force, but only to kill some substantial fraction by long-range fires. As indicated in Table 1, we set the upper limit at 4,000 AFVs. We select 500 vehicles as our minimum value of Kills.

Our upper limit on Red's speed, V , is 100 kilometers per day. Historically, military units of division size and larger have traveled slower than this, sometimes much slower. We select a lower limit of 20 kilometers per day, which might apply because of Blue or our defended ally creating bottlenecks, poor Red command and control after interdiction attacks, or other factors.

The wait time T_{start} (or start time, with the terms used interchangeably) represents a number of phenomena that are treated more completely in the more detailed model as discussed later. For aircraft that cannot fly effectively in the face of air defenses, the wait time represents the time needed to suppress enemy air defenses (SEAD). For weapons unaffected by air defenses (missiles, stealth aircraft), it represents the time needed to establish a good C⁴ISR system to locate and identify areas rich in targets. Our range of wait times is from zero to eight days. This may be viewed as conservative, but future air defenses could be quite challenging, especially with netting and with the tactic mentioned earlier of not revealing some of the air defenses until several days into the war.

The number of kills per day is affected by both the number of shooters (aircraft or missiles) and the effectiveness of each shooter. While the detailed model deals with these factors individually, the aggregate model combines them into this single parameter. We consider a minimum of 100 kills per day. This might correspond, for example, to employing a squadron of 18 or 24 F-15 or F-22 aircraft against the Red column, each of which flies two sorties per day and kills two or three AFVs per sortie. Or it might correspond to a force two to three times larger, but with sortie rates and productivities limited by chemical attacks and imperfect command and control. We consider a maximum of 1000 kills per day.

Plots in Difficulty Space

It is useful to distinguish between the *difficulty* assumed for the challenge and the *capabilities* assumed in attempting to meet it. We can consider difficulty to be defined by the distance within which we seek to halt the invasion and the kills required to bring about that halt. These two dimensions can be used to depict a difficulty space (Figure 11). Difficulty is higher toward the lower right.

The difficulties in the lower left and upper right portions of the shaded region are comparable, but they pose different challenges for Blue. If a halt requires only a few kills but Blue needs to bring about the halt quickly, there will be a premium on quick success. Blue must have shooters present right away, and they must be able to fly with no delay. Measures that help Blue suppress enemy air defenses quickly will be especially valuable, as will measures that cut

down the time for Blue shooters to become fully effective (e.g., C⁴ISR setup time). Advance warning will be extremely valuable. Conversely, if a halt requires a large number of kills but offers substantial depth in which to accomplish them, low effectiveness in the first few days is not so costly. Having a large number of shooters will be important.

To discuss these two cases, for some of our analyses we will single out two individual points in difficulty space. The first is to kill many (4000) AFVs, but with significant depth (300 kilometers). This envisions, e.g., an attack by Iraq on Kuwait and Saudi Arabia by about ten divisions of 800 armored vehicles each, of which half must be killed to halt the column. The U.S. objective is to stop them before they reach the coast of the Persian Gulf. The second is to kill a small number (500) of AFVs quickly (before they travel 100 kilometers). This envisions an attack by three slightly under-strength divisions, only one quarter of whose AFVs must be killed to halt them because morale is low.

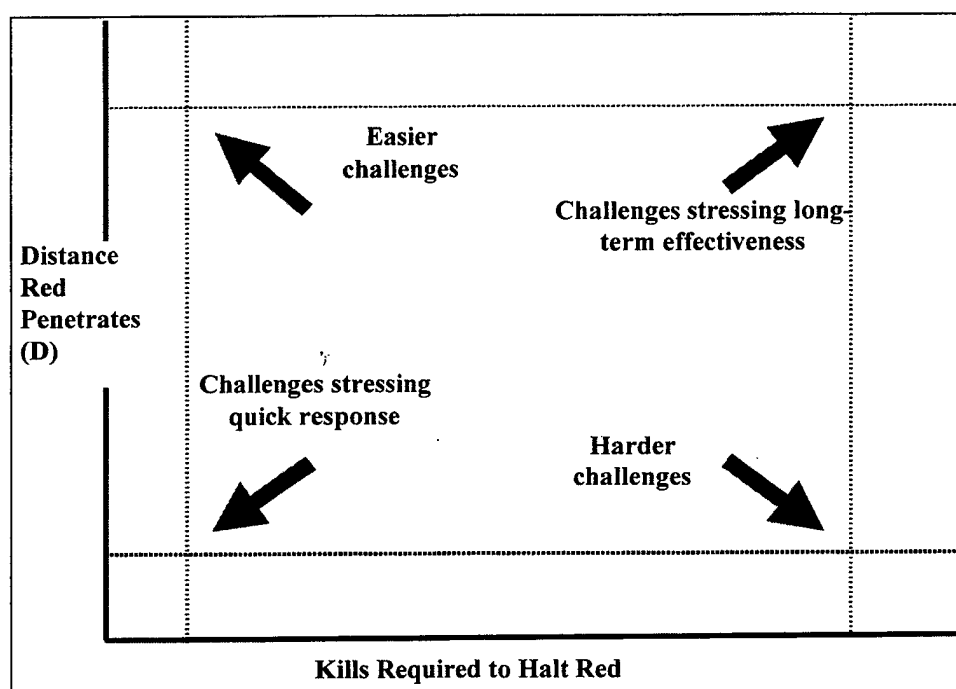


Figure 11—Difficulty Space

Blue's *capability* is described by a combination of the remaining three parameters, Kills, T_{start} , and V . For this purpose we consider Blue's ability to keep Red's movement rate to speed V as a "capability." For example, the more obstacles Blue can create and the more it can use the leading-edge strategy described above, the lower V may be.

With this terminology, a given capability case generates an "iso-difficulty line" in difficulty space, as shown in Figure 12. That is, given a particular level of capability, Blue can bring about a halt anywhere along the line. If he must kill more to achieve a halt, then so also will the maximum distance of Red penetration increase. Conversely, if Red is small and has low morale, then the kills required may be small and the halt distance can be short.

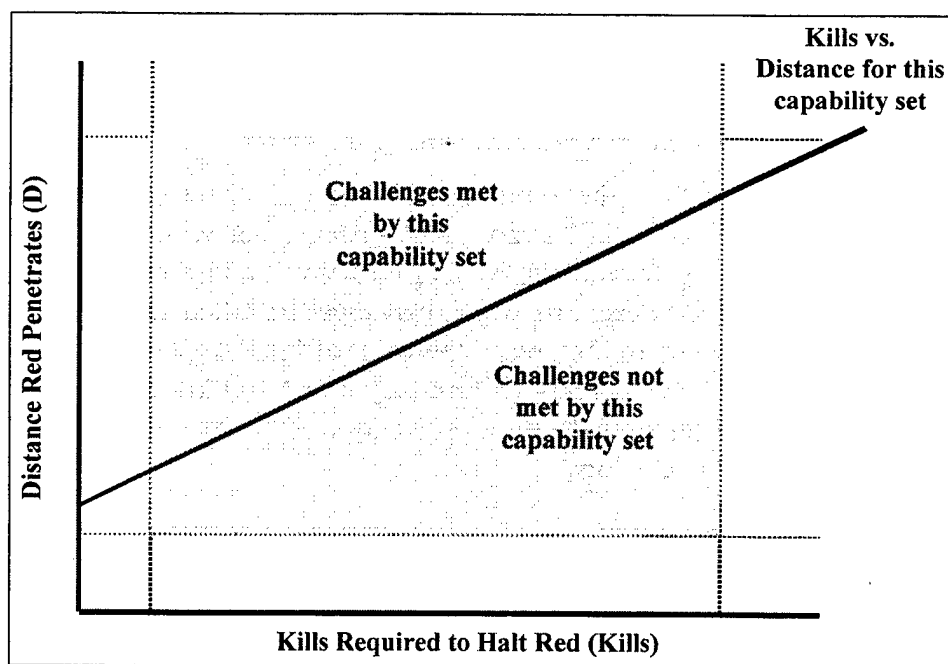


Figure 12—Good and Bad Regions

The shaded region of Figure 12 is the interesting region of difficulty space as delimited by the upper and lower limits on Kills and D from Table 1. No point in the interesting (shaded) region is so hard that it cannot be met with some set of capabilities consistent with Table 1, and no point is so easy that it is met by all the capability sets. To meet the hardest challenges (killing 4000 Red AFVs before they penetrate 300 km), Red's speed V must be low and Blue must be able to begin flying anti-armor missions quickly (T_{start} small) and effectively (KPD large). To fail at the easiest challenges it is only necessary that Blue be forced to delay the start of anti-armor missions for a substantial time (T_{start} large). For example, if $T_{\text{start}} = 8$ days and Red's speed is 75 km/day, Red will have traveled 600 km before Blue flies a single mission against Red's column.

One measure of a given set of capabilities is the "probability of success" in the limited scenario space, i.e., the fraction of the difficulty space the challenge set can handle (the area above the line in Figure 12). A more complex measure would have a utility function for different outcomes, and would then weight the expected utility of the capability set over the cases.

Given uncertainty about the actual wait time, movement speed, and kills per day after the wait time, how well could the U.S. do? Using the uncertainty ranges from Table 1 and assuming uniform probabilities of the capability parameters within those ranges, what fraction of cases within the interesting part of difficulty space could be handled? Figure 13 plots this fraction as a function of how many AFVs must be killed and the distance within which the halt must be achieved. Figure 13 can be understood as saying, e.g., that for only 20% of the capability cases could the U.S. bring about a halt within 300 km if it required killing 4000 vehicles. The odds would be even poorer (about 10%) for a case requiring that 500 vehicles be killed within 100 km. The point, here, is that the U.S. should seek capabilities that greatly improve the odds.

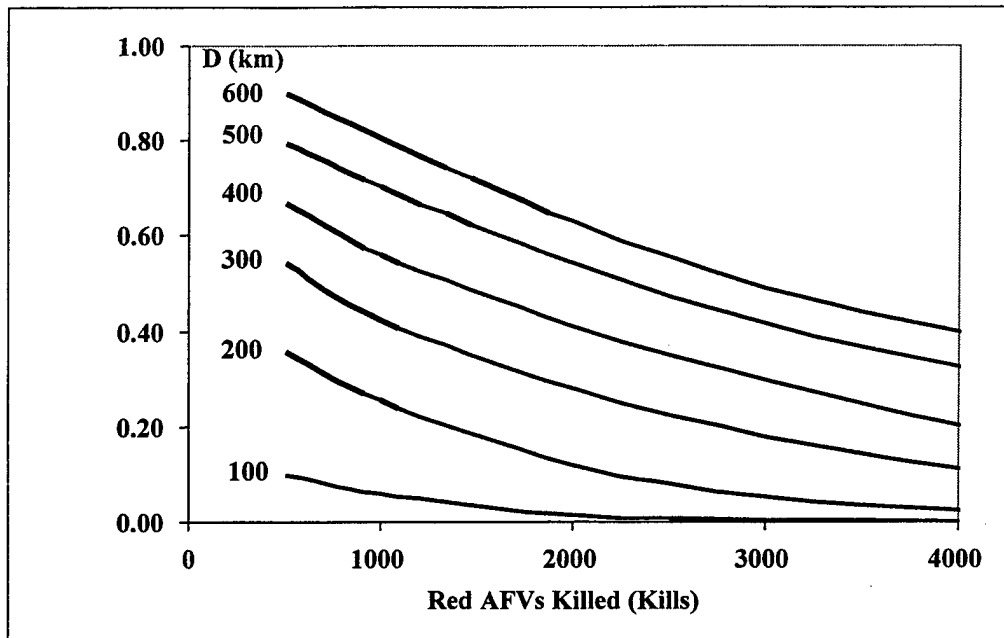


Figure 13—“Probability” of Success (Fraction of Successful Cases) Given Uncertain Capabilities as in Table 1

Seeking Robust Capabilities

Figures 14 and 15 show two plots in Blue capability space, showing tradeoffs among capabilities for each of two requirement surfaces. Capabilities below the surfaces meet the requirement.

For both challenges the bulk of successful capability sets lie in the far corner, where the speed V is low, the wait time T_{start} is short, and the kills per day KPD is high. But the trade-offs among these parameters are quite different. In the upper chart (killing 500 AFVs in 100 kilometers) the bulk of the successful responses are concentrated against the back wall where the wait time is short. In fact, for large enough wait times there are no successful responses with V above its lower limit of 20 kilometers per day. In the lower chart (killing 4000 AFVs in 300 kilometers) successful capability sets are concentrated against the right wall, where kills per day are high. In both cases, slowing Red (moving lower on the vertical axis) greatly increases the ranges the other two response parameters can be in.

Responses That Kill 500 Red AFVs Within 100 Kilometers

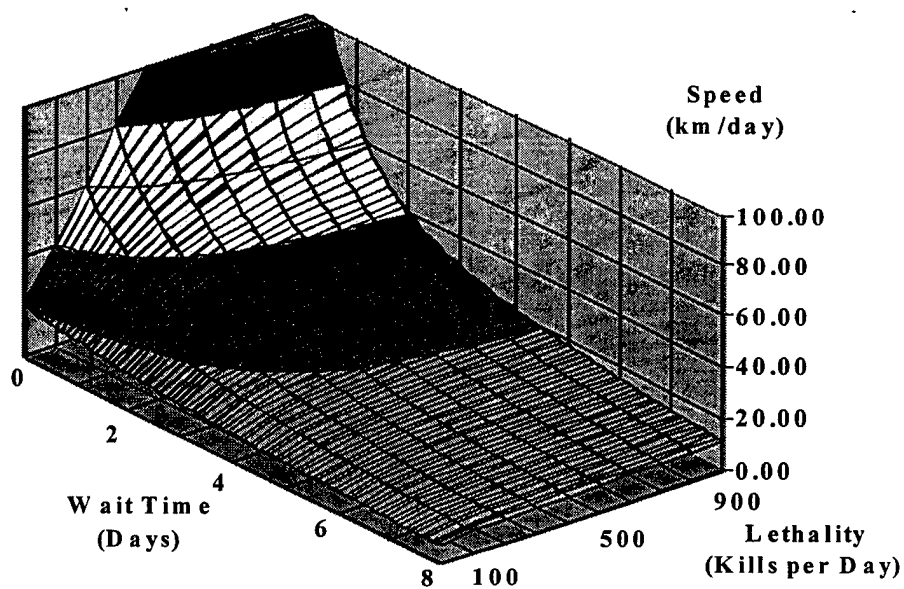


Figure 14—Capability Surfaces for the Small, Slow Threat

Responses That Kill 4000 Red AFVs Within 300 Kilometers

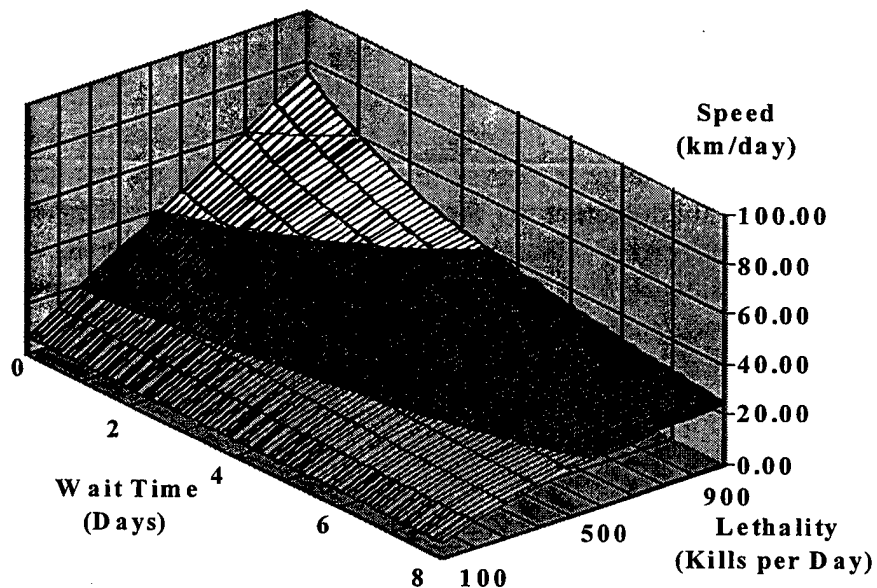
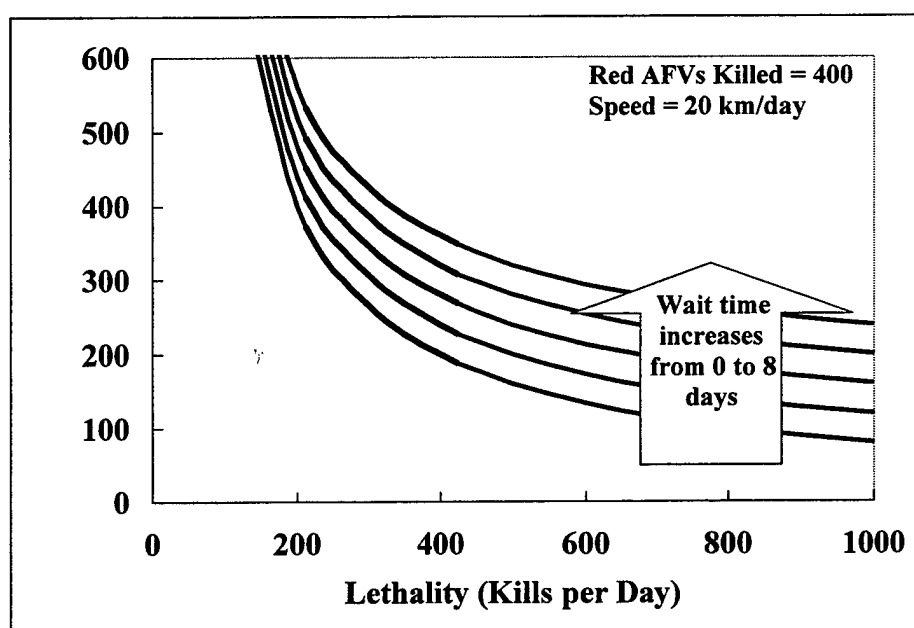


Figure 15—Capability Surfaces for the Larger, Fast Threat

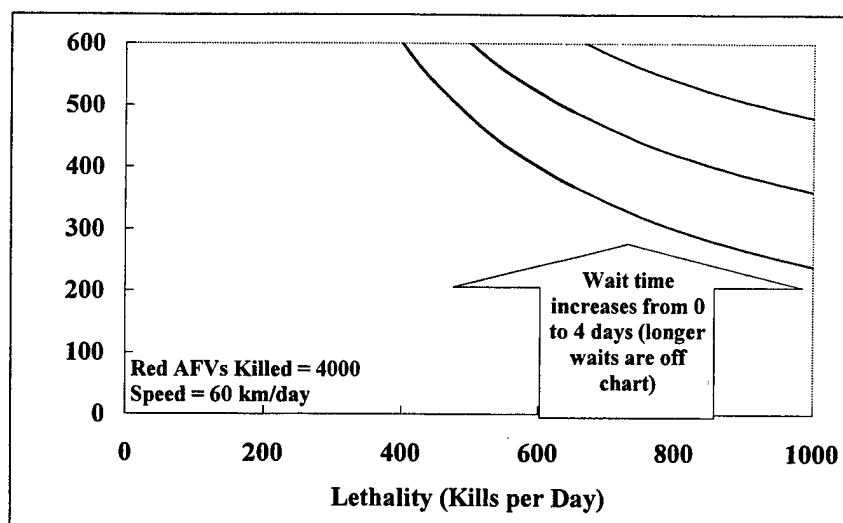
From Figures 14 and 15 we observe that speed V is extremely important and that so also is wait time T_{start} . We see that in the very-early-halt of Figure 14, even against a small threat, wait time can scarcely be more than a few days. There is a bit more slack in the case of stopping a larger threat within 300 km, but not much. In both cases, increasing lethality is good, but not as dramatic.

What It Takes for Success

Given the extreme significance of movement rate, it seems useful to consider two cases for that and show how results then depend on lethality and wait time. Figure 16 and 17 do so. Again we see the need for both high lethality and short wait times if we seek early halts.



*Figure 16—Penetration Distance versus Lethality and Wait Time
(Smaller, Slower Threat)*



*Figure 17—Penetration Versus Lethality and Wait Time
(Larger, Faster Threat)*

A MORE DETAILED EXPLORATION OF EARLY KILLS

VARIABLES OF THE MORE DETAILED DEPICTION

An important conclusion from the initial exploration is that “wait time” is a serious problem—especially when we consider challenges involving short penetration distances. Or, to put it differently, we need to focus concept development on ways to assure early kills. In this section we go into somewhat more detail in order to do so. The results relate closely to many issues examined by the DSB.

As discussed earlier in the paper, our model treats a number of issues at alternative levels of resolution. In the simplest version, we have only the five variables of Table 1. However, if we include more of the details and rearrange to focus on early kills, we have the variables and relationships shown in Figure 18. First, Blue can ensure that he has adequate forces in place early, either by having strong forward-deployed forces, or by having enough warning to build a substantial force before D-Day. Second, Blue can take steps to apply those forces to Red’s advance early-on in the Halt phase, by either reducing the SEAD time or by fielding weapon systems that can fly against armored targets before SEAD is accomplished. Third, he can make sure that his forces are effective from the very start, requiring little time to gain competence and employing C⁴ISR assets that become useful quickly.

These methods interact with one another (Figure 18), so if Blue seeks improvements in one of them the payoff from improving the others will change. We examine several cases of this using a series of outcome tables (Figure 19). Obviously, these can be turned into conventional graphs with “precise numbers,” but the fuzzy tables are perhaps more to the point.²⁴

²⁴ For detailed documentation and more extensive analysis, see Davis et al. (forthcoming).

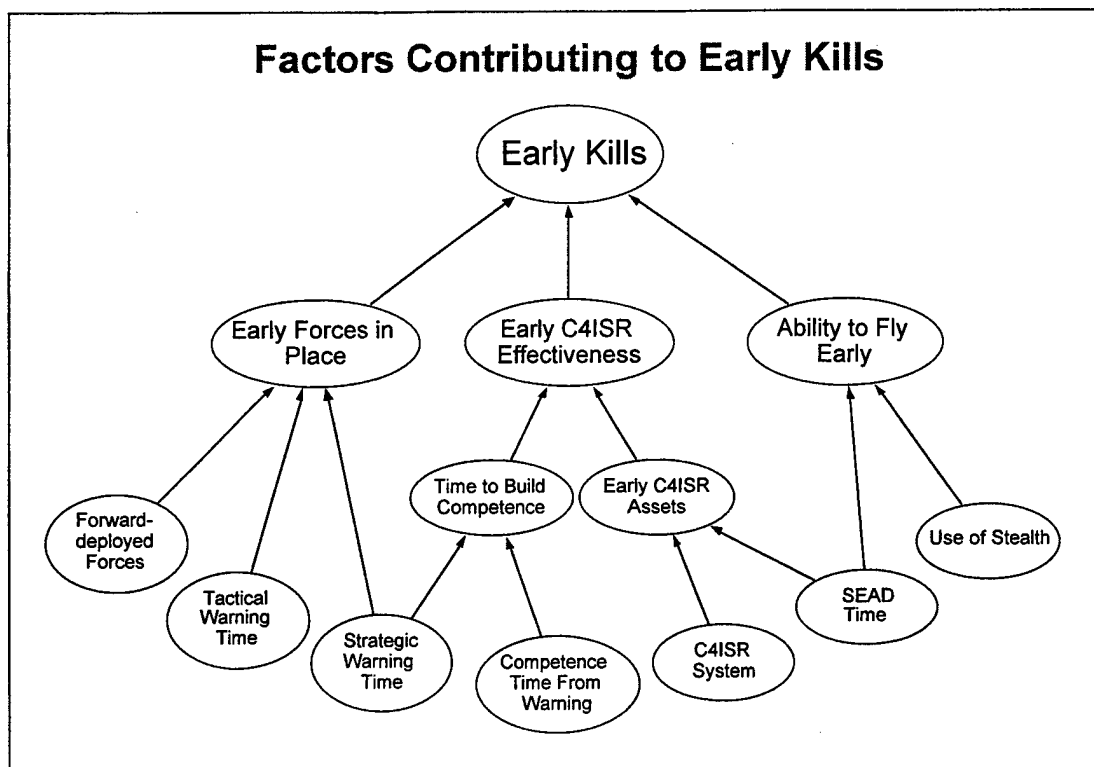


Figure 18—Factors Affecting Early Kills

EARLY FORCES IN PLACE

Having an adequate force in place is key to Blue's success. If an adequately strong, forward-deployed, Blue force is within striking distance of the theatre, the warning time Blue has before the attack is irrelevant (although the Strategic Warning Time is also linked to how quickly Blue's C⁴ISR assets become effective).

Absent a sufficient forward-deployed force, Blue must rely on the warning time to build such a force. The strategic warning time is the time before D-Day at which Blue can take relatively risk-free and non-controversial measures to prepare for possible action (e.g., deploy an additional CVBG or "arsenal submarine" to the region). The Tactical Warning Time is the time for full-scale deployment before D-Day (i.e., the time between C-Day and D-Day).

In this case, we assume that a strategic warning time of 8 days allows the second CVBG to arrive at D-Day plus 2 days, early enough for its F/A-18s to contribute to all but the shortest of engagements. With a strategic warning time of 2 days, the second CVBG does not arrive until day 8, by which time Red has made significant advances.

Tactical warning times of 2 and 8 days simply indicate how long Blue has to build its non-CVBG based force in the theater. With the shorter Tactical Warning Time, Red begins its march facing 60 fewer F-22s and 60 fewer F-15s (in the sample deployment scenario used by the model).

ABILITY TO FLY EARLY

With a non-stealthy force, Blue's ability to fly early is determined by its ability to suppress Red's air defenses quickly. A long SEAD time essentially grants Red a "free movement" period during which only a portion (if any) of Blue's assets can be applied against Red.

However, if Blue has a stealthy force, Blue can immediately apply its full force against Red, regardless of the status of Red's air defenses.

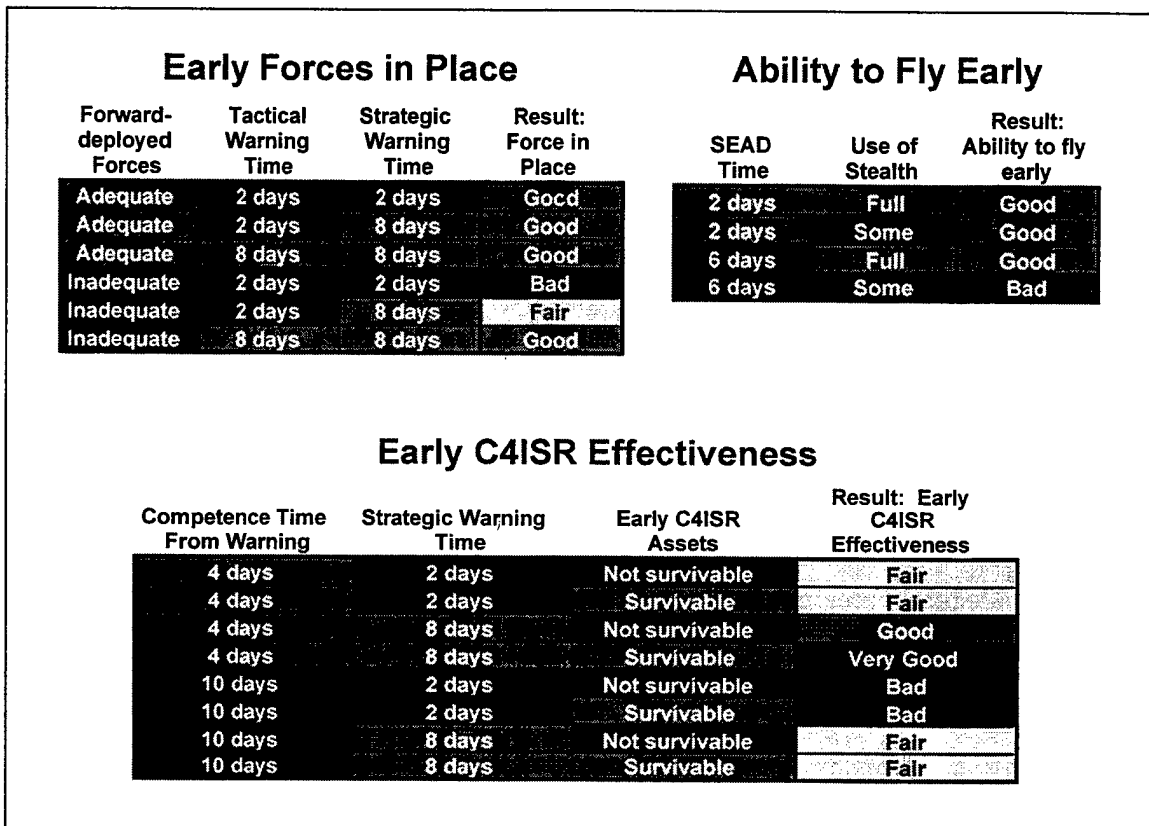


Figure 19—Interaction of System Capabilities

EARLY C⁴ISR EFFECTIVENESS

Figure 19 also indicates that "Gain-Competence Time" (measured from Strategic Warning) and "Strategic Warning Time" combine to determine how quickly, after D-Day, Blue climbs its "learning curve" for C⁴ISR effectiveness.

"Early C⁴ISR Assets" expresses how quickly C⁴ISR assets can be used in the theater. We considered three levels of C⁴ISR system. Because the model's "Base" system is not survivable under Red's air defense efforts, it would only be partially usable on D-Day, and would become more useful as SEAD is accomplished. The "High End" system in the model is robustly survivable, utilizing stealth and/or space-based assets to avoid Red's air defenses, and is fully useful right away.

When the "High End" system is used and a short competence time/long strategic warning time allow Blue to be fully along its C⁴ISR learning curve by D-Day, Blue's C⁴ISR assets are fully effective from D-Day forward. In this case, a Very Good rating is given, indicating there are no degrades at all due to the Early C⁴ISR factors.

In addition, the High End C⁴ISR system provides Blue with an enhanced Engagement Factor, which is a multiplier to Blue's kill rate. For a Base System, this factor is 0.75. For Blue's High End system, the multiplier is 1.25. Thus, the High End system not only improves Blue's early effectiveness, but increases its sustained kill rate, as well.

It is worth elaborating a bit on the issue of gain-competence time because doing so will once again illustrate the interdependence of factors' influences. Suppose SEAD takes a long time and few Blue weapon systems can fly anti-armor missions until SEAD is accomplished. In that case, making the effort to be able to gain competence quickly—in 4 rather than 10 days—has little benefit (Figure 20). But if SEAD is accomplished quickly (2 days rather than, say, 6), or if most Blue weapon systems can execute anti-armor missions early in spite of Red air defenses, then it pays considerably to be able to gain competence quickly.

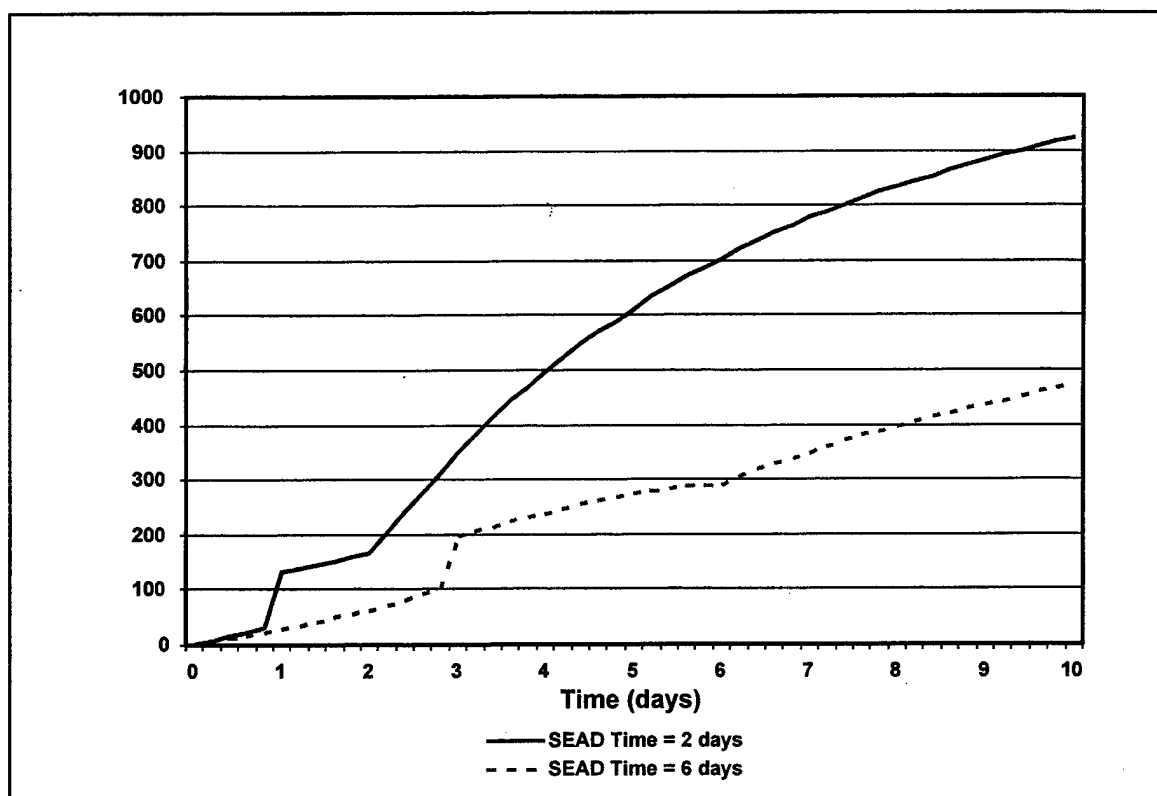


Figure 20—Value of Reduced Gain-Competence Time (4 rather than 10 days) Depends on SEAD Time

SUMMARY SYSTEM DEPICTION OF CAPABILITY INTERACTIONS

Figure 21 summarizes a large number of relatively detailed cases succinctly. Each column is a case, with the bottom cell showing the quality of the outcome. The upper table's color coding assumes the objective of holding Red to less than 100 km (in Kuwait). The lower table uses a somewhat more permissive strategy that considers holding penetrations in a large-invasion case to less than 300 km to be a success. The outcomes shown in the two tables are, respectively, for the small and large threat discussed earlier in the paper. The above calculations were made based on a "standard" Blue force and set of scenario assumptions as described in Appendix A. Chemical attacks would have worsened results substantially by reducing the kills per shooter-day. However, it should be possible to buy back some of the kills—and even improve upon the outcomes, despite chemical attacks on forward bases—if the United States proceeds with some of the many improvement measures discussed in the DSB study. These include upgrading medium- and long-range aircraft for interdiction missions, fitting many surface ships with missiles suitable for interdiction, and deploying an arsenal submarine. Further, by moving to smaller munitions and solving a variety of C4ISR problems, U.S. forces would be able to improve substantially upon the outcomes shown.

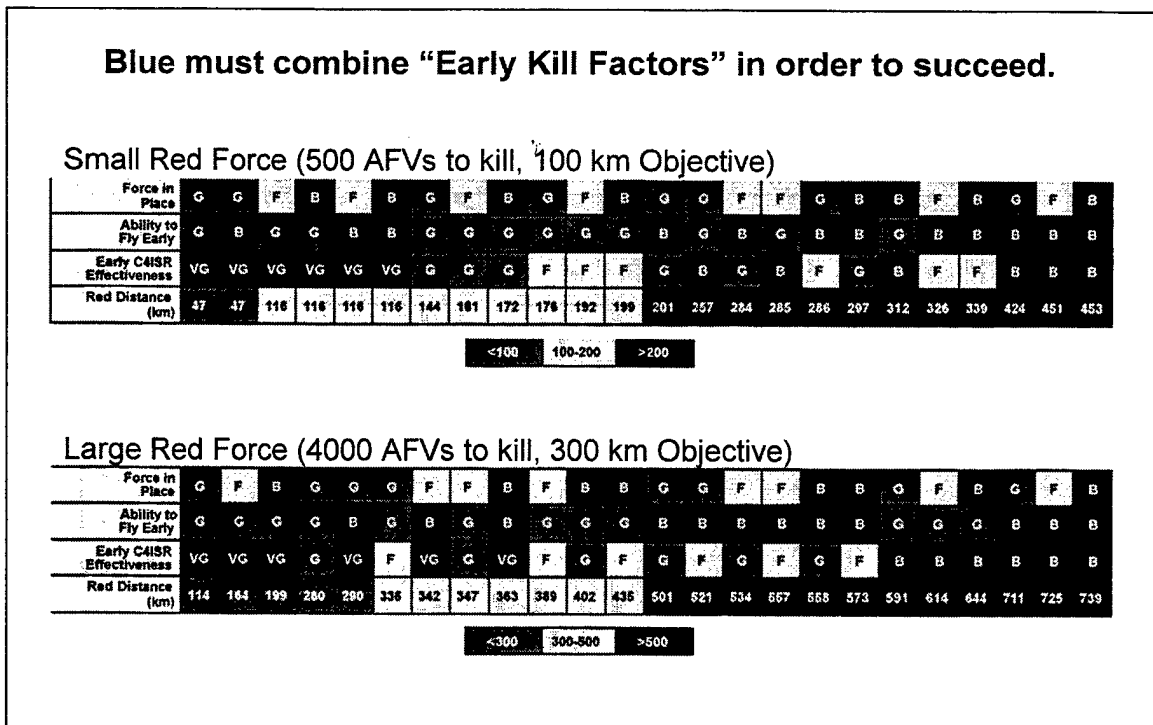


Figure 21—Summary of Interactions

With that background, let us review briefly the ways in which variables interact as discussed in Figure 21 for a base case.

For the small Red force that must be stopped quickly, the ability to field a C⁴ISR system with a "Very Good" rating goes a long way towards allowing Blue to achieve his goal, or at least to

come close. The Very Good C⁴ISR rating conveys Blue's use of an advanced, high-end C⁴ISR system which uses stealthy or space-based assets to allow it to be fielded regardless of the status of the SEAD campaign. In the "small Red" scenario, this is particularly important, because it allows Blue to fire his missiles effectively almost immediately, and since the Red force is small, Blue's missile kills are a significant portion of his total kill requirement. The High End C⁴ISR system, as mentioned earlier, also gives Blue a favorable engagement factor, which improves Blue's overall combat ability by 67% over the Base system used elsewhere in the calculations.

Absent an excellent rating for Early C⁴ISR assets, Blue must either reduce the time to suppress Red's air defenses, or to be able to field attack platforms which are stealthy and able to execute attacks even before SEAD is accomplished. Without this ability, Blue can only achieve poor results.

When facing a large Red force, Blue's success is not so dependent on being able to field excellent C⁴ISR assets, but rather is linked to Blue's ability to do all things well. With the longer distance to work with, though, Blue may be able to overcome unfavorable values of some factors by being especially good at others.

Figure 22 now summarizes some of the ways in which Blue can take control of his "Early Attack Factors" and some possible countermeasures by Red.

Blue's ability to have forces in place before Red's attack begins relies on a combination of the forward-deployed forces he has in the area and on the warning time Blue has before Red marches. By implementing an ability to continuously gather good information on the events in a region, Blue can affect both these parameters. Better information would allow Blue to "hedge" with proactive forward-deployment, and would also alert Blue as early as possible to any preparations Red might be making before an invasion. As a countermeasure, Red could take great care to mask his in-country troop movement and border massing, and thus give Blue as little warning as possible of an upcoming action, but to do so would limit, possibly severely, Red's ability to assemble adequate combat and logistical support for an effective engagement.

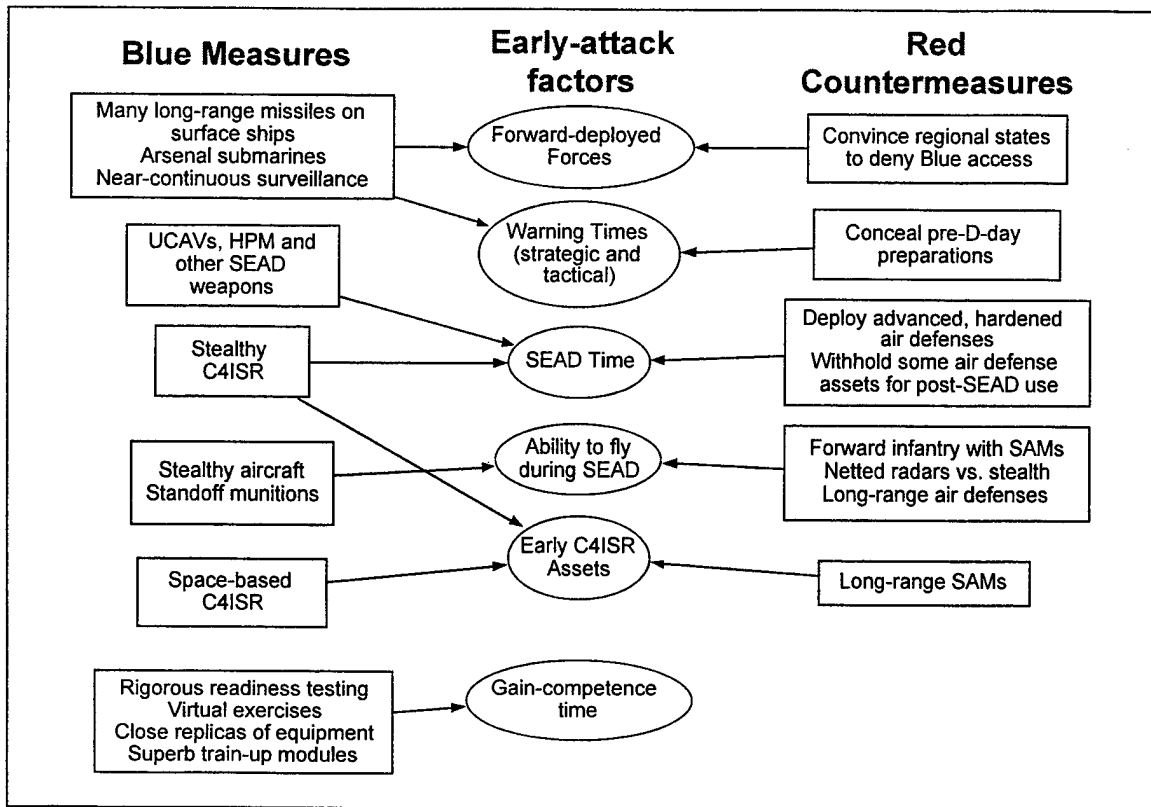


Figure 22—Measures and Countermeasures Affecting Early Kills

Being able to use his assets early is also key to Blue's success in the halt problem, and to accomplish this, Blue must either carry out his SEAD activities very quickly, or be able to fly effectively before the SEAD campaign is complete. The development and application of advanced, stealthy C⁴ISR assets that would allow Blue to locate and target Red's air defenses, as well as the forward-deployment of robust SEAD munitions and attack platforms, would help Blue to carry out his SEAD campaign as quickly as possible. Further, if Blue can utilize attack platforms that employ stealth and/or standoff munitions, he can attack Red armor even before SEAD is accomplished.

One possible Red countermeasure to spoil Blue's early attack ability is to withhold some of his air defense assets to be used later in the campaign. If Red can create uncertainty as to whether or not SEAD has been accomplished, he can cause a risk-averse Blue to delay his armor attacks longer than would otherwise be necessary, or can cause possibly significant losses if Blue chooses to fly vulnerable platforms when some of Red's air defenses remain. Otherwise, Red's ability to counter these measures depends on his ability to develop and field air defense systems that can penetrate stealth or have long ranges such that they could be applied against stand-off weaponry.

Finally, Blue's early C⁴ISR capability can be enhanced by developing and deploying stealthy, space-based, or "disposable" C⁴ISR assets to provide Blue with the situational awareness to improve the effectiveness of his early sorties. Improved training techniques, which move Blue quickly along his in-theater C⁴ISR learning curve will also improve his early C⁴ISR situation.

Red can certainly employ tactics to limit Blue's ability to observe and target him. Red should, as much as possible, take advantage of whatever cover is available or can be created to hide his tactical situation from Blue. By surprising Blue as much as possible, Red can force Blue to operate, in the early parts of the campaign, without a complete C⁴ISR network in place, and cause Blue to use precious campaign time to gain competence in its use (as noted above, though, Red's efforts to hide his preparations may make it difficult to assemble the infrastructure needed for a powerful assault). Red can also intensify his efforts to destroy Blue's information-gathering network by concentrating his air defenses on C⁴ISR assets, or even by developing or otherwise acquiring anti-satellite munitions for use against Blue's space-based assets.

CONCLUSIONS

To summarize the results of this broad exploration of how potential capabilities would be useful in addressing the operational challenge of an early halt, the following appear to us most significant

1. The early halt mission requires three generic capabilities:

- Slow Red down;
- Attack without delay;
- Kill at a high rate.

While exceptional competence at any one can substitute for the others to some extent, we cannot afford to be really bad at any of them.

2. Slowing Red's advance rate is critical, but has not been adequately studied. It is likely that a combination of early interdiction and operations on the ground by defended allies and U.S. special forces will prove desirable. What is feasible is highly dependent on terrain and scenario.
3. To find and attack an invader without delay, the U.S. will need high competence in its C³I and RSTA operations from virtually the moment of the onset of war. Although it is utterly ahistorical to do so, most studies *assume* this without comment. Testing this assumption—and developing methods for training the relevant staffs quickly during crisis and deployment—should be a priority task for joint experimentation.
4. Enemy air defenses may inhibit our RSTA as well as our attacking forces. Since platforms like J-STARS could be highly vulnerable, this implies the need for early deployment of survivable RSTA assets such as high-endurance low-observable UAVs, satellites, or both. This is because—despite many studies assuming rapid completion of SEAD—it is questionable whether that could be achieved in practice against a clever adversary who might, for example, maintain some SAMS in hiding until several days into the campaign. Mobile SAMS and integrated air defenses would pose additional serious difficulties.
5. For related reasons, it would be valuable to have more delivery platforms that could employ weapons *before* completion of SEAD. These might be, for example, stealthy

future bombers or UCAVs, MLRS/ATACMS, or naval-based missiles such as those that might be launched from converted Trident submarines.

6. Although most studies and war games have assumed that the effects of fires are proportional to the number of sorties or shots, it would not be surprising if there were sharply diminishing returns. For example, kills could be limited by the ability of the C4ISR system to find targets. This should be tested with both high-resolution simulation and joint experiments confronting human operators with large numbers of targets, large numbers of platforms and weapons, short decision times, and with imperfect RSTA, fusion, and decision aids.
7. The effectiveness of air-delivered LRF might be drastically reduced by plausible tactical countermeasures such as dash tactics in which ground forces would be on the road only a few hours per day, at random times, and in hiding at other times. Implicit in most low-resolution work is the image of long uniform columns and movement matched in time to the uniform arrival of sorties scheduled well in advance. If the attacker used dash tactics, most of the sorties would have no targets—unless they could detect and attack static non-hot forces under camouflage or in terrain-masked hides. The counter countermeasures for air forces here would include long-loiter missions (essentially "CAP missions"), strip alert, super-long-loiter systems such as might be possible with modified bombers or other large platforms, FOLPEN, and a mix of weapons for striking moving area targets and stationary area and point targets. Many of these were in fact discussed to some extent in the summer study's three concept teams.

ANNEX A: Description of the Model and Parameters of the Scenarios Examined

OVERVIEW OF THE MODEL

Figure A-1 describes the process flow of the overall model. As illustrated by Figure 3 in the main text, the Deployment of Blue Shooters node takes information regarding Blue's forward-deployed assets, his warning time, deployment rates (for various types of shooters), losses taken, and deployment or theater capacity limits to calculate the number of shooters Blue has available in the theater at a given time. The Effectiveness of Blue Shooters node (refer to Figures 5-7) then uses inputs for Blue's C4ISR capabilities, kill and sortie rates for Blue's various shooter types, and some possible strategies Red and Blue might use (e.g., dash-and-hide tactics for Red and concentrating attacks on Red's front edge of advance for Blue) to determine the effectiveness of Blue's sorties against Red's armor. At this stage, the model also tests to see if the early degrades to Blue's C4ISR capabilities have mitigated sufficiently to trigger the launch of Blue's missiles. The Employment of Blue Shooters node (Figure 4) then allocates some fraction of each type of Blue's available shooters to anti-armor missions, and may withhold some of Blue's shooters if SEAD is still ongoing.

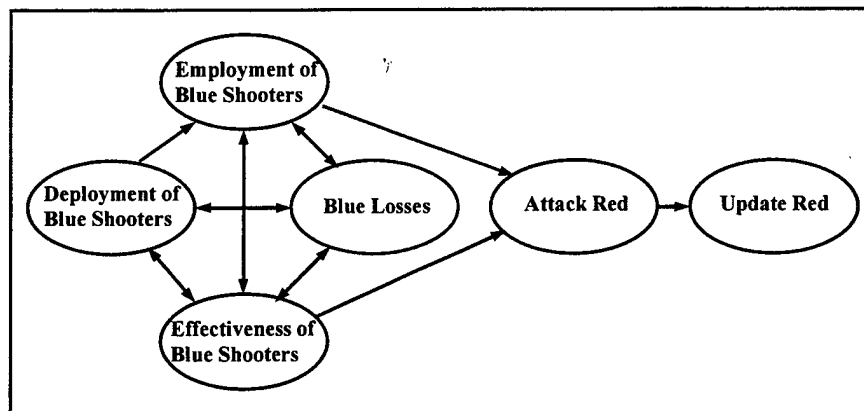


Figure A-1. Process flow of the Halt model used in this work.

The two nodes, Attack Red and Update Red, correspond to the Attack and Update Red step from the top-level view of Figure 2, main text. At the Attack Red node, Blue's shooters then attack Red's armor, generating Red AFV "stops" (includes both Red AFVs killed and disabled) and accruing shooter losses (the Blue Losses node) due to Red's air defenses (if active). (In the main text we ignored shooter losses, but the model does consider them.) Finally, the Update Red node updates Red's position and numbers, making use of Red's speed of advance (Figure 8, main text). The next "wave" of Blue attacks then begins, and the model updates Blue's numbers for losses taken in the last wave and new deployments that may have arrived.

The following sections describe the values taken on by various inputs to the model described above.

BLUE INPUT PARAMETERS

Blue's force strength, deployment information, shooter capabilities, SEAD campaign length, C4ISR assets, and strategy elements are described in Blue's input parameters to the Halt model. All of the information about Blue's shooters, including forward-deployed units, deployment rates, theater capacity limits, shooter effectiveness, is given in the Blue Shooter Inputs matrix, which is indexed by Blue's shooter types and the eleven characteristics (see Table A-2) that each shooter type can possess. For this work, a Base Force Mix was described, which included F-15s, F/A-18s, B-1s, F-22s and N/TACMs fired from a postulated arsenal ship (converted from a Trident submarine). Table A-3 shows the Blue Shooter Input matrix used for the force mix employed in the model.

Parameter	Description	Value
Blue Shooter Inputs	Contains information regarding Blue's shooters and their characteristics (deployment rate, kills per sorties, etc.).	Described in Table A-2
Mode of Blue Attack	Blue may choose to concentrate his attacks at the front of Red's forces, or may distribute his attacks throughout Red's ranks. If Blue attacks at Red's front, he takes some degrade to the effectiveness of his attacks, but he need only kill some portion of a leading edge segment to render the segment ineffective, and can "roll back" the Red advance as front segments are killed.	Front Attack is default.
SEAD Time	The number of days required to suppress Red's air defenses.	Ranges from 0 to 8 days; "Good" value is 2 days; "Bad" value is 6 days.
Flexibility of Fires	On a scale from 1 to 9, this indicates Blue's ability to adapt his attack strategy to the movement patterns of Red.	Ranges from 1 to 9. Default value is 5.
CVBG Arrival	The number of days after Strategic Warning that a second CVBG arrives in the theater (with 60 F/A-18s).	Default value is 10 days.
Competence Time, From Warning	The number of days, from Strategic Warning, that it takes Blue to build competence in the use of his C4ISR assets.	Ranges from 2 to 12 days. "Good" value is 4 days, "Bad" value is 10 days.
C4ISR System	Determines the C4ISR Engagement Factor, which is a multiplier to overall effectiveness, and the Early C4ISR Degradation. From least effective to most effective, the possible systems are Base, Enhanced, and HighEnd (which is assumed to be stealthy or space-based, and suffers no early degrades).	Base, Enhanced, or HighEnd.
Missile Effectiveness Threshold	Blue will withhold firing his missiles until the early degrade (due to the Early C4ISR Degradation and the C4ISR Competence Buildup) becomes greater than this threshold.	Default is 0.75.

Table A-1. Model inputs for Blue's forces

Parameter	Description
Shooters in Theater Initially	The number of shooters of each type forward-deployed to the theater.
Arrival Rate	The number of shooters of each type arriving in the theater each day, once Tactical Warning has begun.
Maximum Deployment	The maximum number of shooters of each type that may be deployed to the theater.
Shooter Capacity Theater	The maximum number of shooters of each type that may be used in the theater at a given time.
Nominal Sorties or Shots per day	The number of sorties or shots per day typically executed by each shooter type.
Nominal Kills per Sortie or Shot	The number of kills achieved by each shooter type in a typical sortie or shot.
Wait time for SEAD	The number of days each shooter type will refrain from flying while waiting on at least some portion of the SEAD campaign to be completed.
Fraction Flying During SEAD	Once each shooter type begins to fly, the fraction of its normal sorties it will fly until SEAD is completed.
Anti-armor Fraction	The fraction of each shooter type's efforts that will be applied to attacking Red AFVs.
Initial Shooter Loss Rate	The initial loss rate of each shooter type per sortie or shot due to Red's air defenses. The loss rate will decline from this value as SEAD is accomplished.
Risk taken by Blue Pilots	On a scale from 1 to 9, the relative risk taken by the pilots of each shooter type. Higher risk leads to higher effectiveness, but a higher loss rate, as well.

Table A-2. Blue Shooter Characteristics and descriptions.

Base Force Mix	F-22 Eqs	F-18 E/F Eqs	B-1 Eqs	F-15E Eqs	Arsenal ship Eqs
Shooters in theater initially	24	60	50	24	1
Arrival Rate	12	If (Time=Cvbg_arrival) Then (60/Timestep) Else 0	0	12	0
Maximum Deployment	144	180	50	144	1
Shooter Capacity Theater	144	180	50	144	5
Nominal Sorties or Shots per day	2.0	2.0	0.5	2.0	500/Timestep
Nominal Kills per Sortie or Shot	2	3	12	3	1
Wait time for SEAD	0	2	4	2	0
Fraction Flying During SEAD	100%	10%	0%	50%	100%
Anti-armor Fraction	0.5	0.5	1.0	0.5	0.5
Initial Shooter Loss Rate	1%	4%	10%	4%	0%
Risk taken by Blue Pilots	5	5	5	5	5

Table A-3. Shooters and shooter characteristics for the Base Force Mix.

RED INPUT PARAMETERS

Table A-4 describes the variables used to parameterize the Red force in the model.

Parameter	Description	Value
Number of Red Divisions	The number of Red divisions taking part in the advance.	Ranges from 1 to 8. Small force is 1; Large force is 8.
Red AFVs per Division	The number of Red armored fighting vehicles in each division (includes tanks, APCs, etc.).	Default is 1000.
Axes of Red Advance	The number of major axes by which the Red force advances.	Default is 1.
Base Red Column Speed	Absent the roll-back from Blue's attacks, the number of km per day travelled by the Red force.	Ranges from 20 to 100. Default is 70.
Columns Within Each Axis	The number of columns within each Red axis (e.g., Red AFVs may ride 2 across on a major road).	Default is 2.
Spacing Between Red AFVs	The mean distance between a Red AFV and the AFV ahead of it, in meters.	Default is 100.
Chemical Weapons/Mining Flag	A flag to note if Red uses or threatens the use of chemical weapons and/or mining of appropriate waterways. If so, Blue Air Force deployment rates and sortie rates are halved, and Blue's carrier-based shooter sortie rates are reduced by a third.	Default is "No."
Red Time Concentration Factor	On a scale from 1 to 9, Red's ability to concentrate his movement during certain parts of the day (e.g., use "dash-and-hide" tactics).	Default is 5.

Table A-4. Input parameters for Red forces.

MODEL ASSUMPTIONS

In the model's calculations, several parameters exist which are not strictly "Blue" or "Red" parameters, but rather represent assumptions about combat rules or situations presented to Blue in a given scenario. These assumptions are specified in Table A-5.

Parameter	Description	Value
Front Halt Fraction	The fraction of forces in a front segment of Red's advance that Blue must kill to stop that segment of advance and "roll back" Red's advance by that segment.	Default is 0.72.
Overall Halt Fraction	The fraction of Red's overall force that Blue must stop in order to cause Red's advance to fall apart, or halt.	Default is 0.5.
Strategic Warning Time	The time (in days) before D-Day during which Blue can take relatively risk-free and non-controversial measures to prepare for a possible Red advance (e.g., deploy a second CVBG or "arsenal submarine" to the region).	Ranges from 0 to 10. "Good" value is 8; "Bad" value is 2.
Tactical Warning Time	The time for full-scale deployment before D-Day (in days)	Ranges from 0 to 10. "Good" value is 8; "Bad" value is 2.

Table A-5. Model Assumptions.

CONTROL PARAMETERS

For the purposes of controlling the incremental steps of the model, the model computed the first 20 days of the Halt campaign (which ensured all Red vehicles were stopped) in steps of 0.2 days each.

ANNEX B: Bibliography

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JOINT OPERATIONS SUPERIORITY IN THE 21ST CENTURY: ANALYTIC SUPPORT TO THE 1998 DEFENSE SCIENCE BOARD²⁵

PREFACE

This document describes RAND research that supported the 1998 Defense Science Board (DSB) Summer Study on *Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010*. More specifically, this work involved assessing several different Joint force concepts that could be applied to resolve a notional high-intensity, quick-reaction scenario around the 2010–2015 time period. RAND supported the DSB through both exploratory analysis and high-resolution simulation-based analysis; this document only covers the high-resolution work.

Research was conducted over a four-month period within two of RAND's federally funded research and development centers (FFRDCs), the Arroyo Center and the National Defense Research Institute (NDRI). More specifically, Arroyo Center research was conducted within the Force Development and Technology Program; NDRI research was conducted within the Acquisition and Technology Policy Center. The work was sponsored, respectively, by the Army's Office of the Deputy Chief of Staff for Operations and Plans and the Office of the Undersecretary of Defense for Acquisition and Technology. The Arroyo Center is sponsored by the United States Army, and NDRI is sponsored by the Office of the Secretary of Defense, the Joint Staff, the unified commands, and the defense agencies.

Any questions regarding the content of this research should be directed to the authors.

SUMMARY

MOTIVATION FOR RESEARCH

Although the defense community has come to endorse "jointness" in military operations, views differ greatly on what operations should look like in the future. *Joint Vision (JV) 2010* provides basic ideas on how people and technologies might best be used to shape Joint warfare in the future, but it is a vision document that is intended to serve as a conceptual template, not a blueprint. The Defense Science Board (DSB) was asked to help move things forward by focusing "on how new capabilities, operational concepts, and different force characteristics can be developed and integrated to underwrite *Joint Vision 2010*."²⁶

This report describes part of RAND's analytical support of the DSB summer study, notably simulation experiments to help explore and assess Joint operational concepts. It builds on related

²⁵ Written by John Matsumura, Randall Steeb, Ernst Isensee, Tom Herbert, Scot Eisenhard, John Gordon.

²⁶ Terms of Reference--Defense Science Board 1998 Summer Study Task Force on Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010.

work done by the authors for a previous DSB effort, *Tactics and Technology for 21st Century Military Superiority*.²⁷ In this year's effort, we not only drew on outcomes of such previous DSB studies, but also included new discussions with warfighters and planners in the Joint warfare community, and interactions with DSB members, to define a range of operational concepts for the future. The strengths and weaknesses of these concepts were explored using man-in-the-loop, high-resolution, stochastic constructive simulation in the context of a single basic scenario with a number of variations. Our intention in this detailed work was to: (1) provide insights and inputs for a broader, exploratory RAND analysis for the DSB, (2) increase dialogue among conceptualizers, users, and developers, and (3) suggest ideas that would indeed help the DSB take *JV 2010* to the next step. An additional objective made clear by the summer study's leadership from the outset was to illustrate the kinds of analysis needed to assess new concepts. That is, the leadership saw the current effort as the beginning of what should be sustained community analytical efforts.

FOUR JOINT CONCEPTS EXPLORED

We examined four very different Joint operational concepts in a notional 2010–2015 scenario designed to highlight issues associated with the phrases such as “information dominance” and “dominant maneuver,” and to do so for operational circumstances different from those heavily studied in recent years. The scenario involved early neutralization/disruption of a highly mobile, elite enemy unit located behind enemy lines with plausible quick reaction U.S. forces. That is, the scenario postulated almost immediate “offensive” operations as part of initial U.S. efforts to help the defending ally stop and defeat the invader. All four concepts involved the aggressive use of long-range attack weapons represented by aircraft delivering standoff weapons such as Joint Standoff Weapon (JSOW) and Navy and Army versions of the Tactical Missile System (TACMS), which were equipped with advanced submunitions. However, the four Joint concepts differed markedly in the level of operational and tactical maneuver with ground force, and how those forces would be used. All four concepts were examined with a range of assumptions about reconnaissance, surveillance, and target acquisition (RSTA) & command and control (C2).

Suppression of enemy air defenses (SEAD) was seen to be a critical precursor to all concepts, since we assumed that an advanced future threat would respond to U.S. air superiority with fully integrated air defenses. We did not directly model or simulate this part of the concepts, but rather, we assumed that enough SEAD capability would be in place to gain access to the deep enemy battlespace (e.g., successfully clearing an airspace corridor to permit short-range standoff weapons to be delivered and to bring in transport aircraft carrying ground forces).²⁸

The first concept explored using long-range, standoff attack alone to neutralize the deep mobile enemy unit. The second concept built on the standoff capability by adding a conventionally organized airborne ground force with updated sensors, C2, and weapons. The third concept used a more agile and more dispersed ground force (sometimes referred to as the

²⁷ Reference RAND document, DB-198-A, *Tactics and Technology for 21st Century Military Superiority: Analytic Support to the Defense Science Board*, J. Matsumura, R. Steeb, T. Herbert, M. Lees, S. Eisenhard, A. Stich, 1997.

²⁸ Since all concepts involve rapid reaction to the invasion in a matter of days, it was deemed unlikely that the entire enemy air defense network could be neutralized. Instead, available SEAD assets were focused strictly on clearing ingress and egress routes and selected areas of operation.

enhanced medium-weight strike force) instead of the conventional airborne force.²⁹ The fourth concept used the same force composition as the third but applied it differently, using the force to attack the relatively “soft” parts of the enemy force rather than the lethal combat units. One measure of effectiveness—kills of enemy and losses of the ground force—is shown in Figure S.1 for the four different concepts (labeled cases 1–4). Each pair of bars in the chart shows, respectively, losses of Red and Blue forces. The last bar-chart pair indicates a representative “equivalent” effect from disruption.

Research Findings

In examining the alternative operational concepts we also addressed three key questions: (1) To what extent can information superiority, via improved RSTA & C2 capabilities and decision-making, enhance future joint operations? (2) How should we think about the relationship between maneuver and firepower, for different RSTA & C2 capabilities? and (3) What are the major factors that affect force effectiveness? Our conclusions follow.

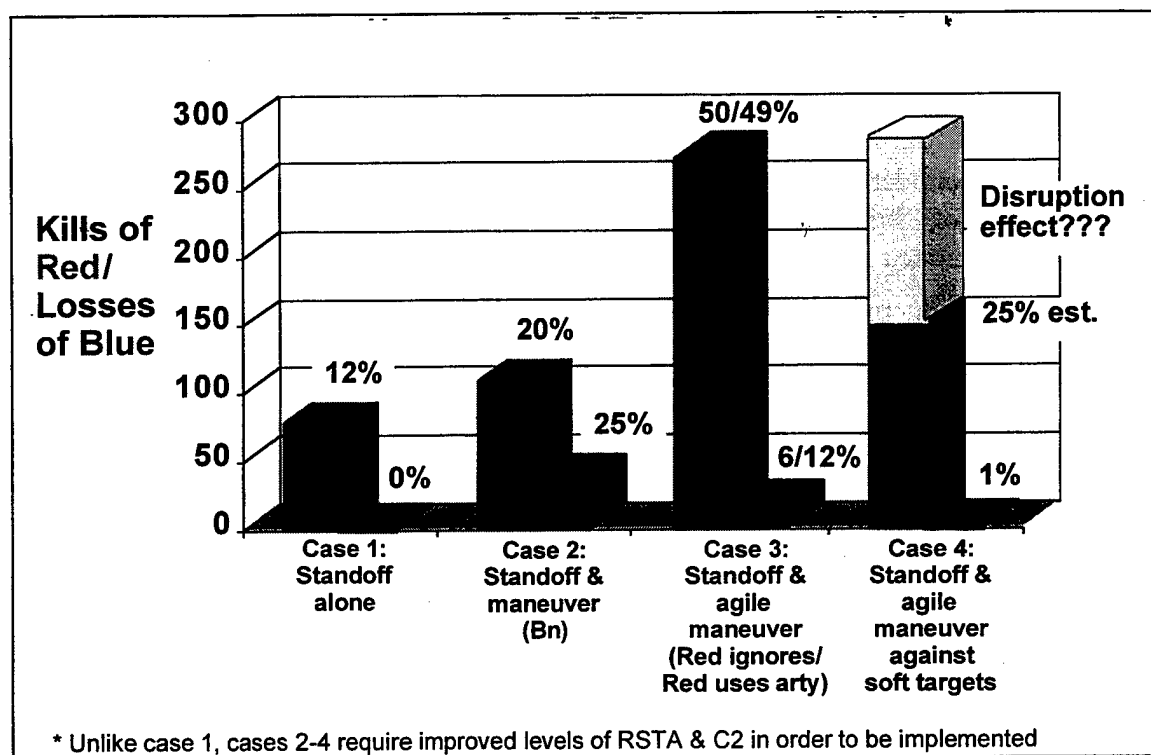


Figure S.1—Increasing Levels of Maneuver Provided Ability to Accomplish Mission: Different Applications Impact Both Survivability and Lethality

²⁹ This concept is one that has many similarities to the USMC’s Hunter Warrior, DARPA’s Small Unit Operations, and TRADOC’s Army After Next Battle Unit and Mobile Strike in that it is a rapidly deployable future force designed around a family of lightweight and agile ground forces.

Improved Decision Making Can Enhance Future Joint Operations

Improved decision making made possible by new RSTA & C2 capabilities was seen to be the key enabler allowing a rapid Joint response (e.g., force insertion and force application) against the rear area of an enemy advance, without the requisite “conventional” build-up time.³⁰ Vulnerable and lucrative areas on the battlefield, which might constitute the enemy's center of gravity, could be targeted for attack. Similarly, the most dangerous and lethal part of the enemy's battlespace could be identified and, in some cases, avoided during force deployment.

However, the Joint task force (JTF) commander's ability to affect the battlespace ultimately was not governed by RSTA & C2 capabilities alone. Even when we assumed a near-perfect (complete, accurate, fused, and timely) RSTA & C2 capability, which greatly improved the planning process, we found that the ability to execute the battle plan fell short in a number of other areas—reinforcing the notion that RSTA & C2 capabilities are only one piece of a larger system. More specifically:

- Enemy air defenses, even if located with advanced RSTA, must be neutralized. Since these systems are likely to be mobile (e.g., SA-12) and can outrange most friendly weapon systems, these defenses must be countered or destroyed quickly. In some cases, it may not be feasible within the time-and-space requirements.
- Ability to conduct standoff operations was largely limited by the weapon system. Long time of flights, limited engagement zones (due to foliage), and imperfect munition logic led to relatively low weapon efficiencies.³¹
- Ability to conduct maneuver operations was seen to be largely limited by intratheater mobility capability. Even if RSTA & C2 were able to provide enough intelligence on where the threat systems were concentrated (including the air defense network), cross-FLOT operations might pose unacceptable risk.

In conjunction with SEAD, air superiority, RSTA & C2, improved capabilities in the areas of maneuver and engagement were seen as necessary to accomplish U.S. objectives in this scenario.

Standoff Engagement and Maneuver Capabilities Complement Each Other

To be able to accomplish early neutralization and otherwise blunt invasions with standoff weapons alone would, of course, be very desirable. Ideally, weapons would be able to: (1)

³⁰ In our assessment of RSTA & C2, we opted for a parametric representation. In modeling RSTA, we used five parameters: comprehensiveness, both in and out of foliage, ability to discriminate, and accuracy and latency. C2 was represented as a time delay. Although other attributes such as false alarm rate and degree of fusion would ideally be included, these were not examined due to time constraints. Also, we did not examine the ability for an enemy force to negate U.S. RSTA & C2 capabilities. Nor did we give the enemy a comparable level of RSTA & C2 that U.S. forces enjoyed. This suggests that our findings, if anything, may err toward the conservative, favoring Blue effectiveness.

³¹ Typically, even with near-perfect RSTA & C2, we saw around 0.3 kills per JSOW and 0.6 kills per TACMS. Foliage presented a key problem in this scenario. When foliage was removed, weapon effectiveness increased roughly 3 fold. Positioning missiles in theater (missiles in a box) to augment standoff fires (e.g., reducing fly out response times) also increased weapon substantially.

perform well in difficult and complex terrain, (2) be insensitive to weather and obscurants, (3) be able to acquire all target types of importance, discriminating among good, unimportant, dead, and decoy targets, and (4) have very fast times to react (perhaps through loitering platforms) or be capable of being retargeted during flight. More generally, they should be adaptable to the changing conditions of the battlefield, whether these are threat controlled or environmentally dominated.³² There are of course physical limitations on how many of these can be achieved in the 2015 time frame.

Currently planned, notional long-range weapon systems are not far enough along to fully capitalize on high-end RSTA & C2 capabilities. From a weapon platform perspective, systems that are physically close to the target and coupled to sensors have opportunities that long-range systems simply do not have. In addition to increased probability of encountering a target, systems that are physically close also have a shorter feedback cycle (e.g., time to determine whether the engagement was successful and whether additional munitions need to be applied).

Although long-range firepower caused some attrition, it had clear limitations in our scenario. When terrain and other physical conditions were changed, the amount of attrition improved. *However, there was little ability to actually control the battlefield with this capability alone. As a result, the enemy could change the conditions back to his favor through a variety of countermeasures.*

From a maneuver perspective, RSTA & C2 tended to be dominant factors—unlike with standoff engagement alone, in which the benefit of RSTA & C2 reached a plateau relatively quickly.

- Because the investment and risk of a maneuver-based operation tends to greatly exceed one that involves standoff engagement alone, RSTA & C2 were seen to be premium assets from a different perspective. Knowing where an enemy is located, what he is doing, and where he is going is critical (more so than with standoff engagement), because the consequences of incomplete and/or inaccurate information can take more catastrophic forms.³³
- Unlike firepower, maneuver provides a means to control the battlespace. In addition to causing shock and efficient selective destruction, it was apparent that many other effects could be achieved (controlling enemy movement, controlling terrain) that were not reasonable expectations with standoff engagement alone.³⁴
- If ground force maneuver in the enemy's rear is needed, as in this scenario, one way to decrease risk might be through the use of unmanned or robotic systems. The success of local indirect fires (missile pods) and other unattended ground sensors and unmanned ground and air vehicles in this study and related studies suggest high potential payoff. Although not studied here, orbiting armed UAVs might yield similar benefits.

³² Ground forces using organic weapons, can do most of these at some level already.

³³ For example, complete destruction of force due to incomplete or inaccurate information resulting in an inappropriate insertion or extraction.

³⁴ The use of remotely delivered mines might have provided a means for greater control; however, without overwatch protection such a minefield is susceptible to being breached.

The engagement process employing standoff, local indirect, and direct fires should embody the most efficient combination and sequencing of weapons, provided necessary deconfliction levels can be obtained. For example, we found that long-range weapons fired from standoff, which characteristically have large-footprint submunitions, could best be used against large target groups moving predictably and toward open areas. In the close, covered terrain examined here, the opportunities for using these weapons were much more limited than expected. Local indirect fire weapons could help establish the conditions for other direct fire weapons and serve also as a means of more robust and selective attrition. These systems can react to smaller exposure intervals than the long-range systems. Direct fire systems provide quick cycle times and shock, offering the highest degree of robustness and efficiency. (See Table S.1 below.) While long-range fires could have been employed in greater numbers, resulting in better overall results, their efficiency would have dropped even farther.

Table S.1

Direct Fire Weapons and Organic Weapons with Updates Were Seen to Be More Efficient (Per Munition) than Long-Range Weapons

Weapon class	Time-of-flight (TOF)/ distance traveled	Number weapons fired/ number targets killed
Direct fire		
- LOSAT	2-3 sec./2-4 km	120/95
Organic indirect fire (w/update)		
- AEFOG-M	2-3 min./5-20 km	144/99
Organic indirect fire (no update)		
- MLRS-Pod (3 subs)	1-2 min./10-40 km	260/65
Long-range standoff fire		
- JSOW (2 subs)	10 min./40 km	144/42
- TACMS (13 subs)	10 min./150+ km	68/35

Other Scenario Variables Can Govern Outcome

Many countermeasure options are available to the future threat postulated in our scenario. He can disperse his forces, move in unpredictable ways, use deception, employ jammers, launch EMP weapons to neutralize parts of the battlefield, use active protection systems, activate counter-recon units, prep the battlespace, etc. Most of these can have a large impact on a standoff firepower-based capability alone. Maneuver—when feasible—would provide some levels of robustness, allowing some counter-conditioning of the battlespace. In addition to threat countermeasures, the more obvious scenario variable is weather. It can degrade U.S. overhead and ground sensor capability, deny use of air power, negate effectiveness of smart munitions, reduce trafficability of maneuver forces, reduce throughput and timeliness of C2, among others. Other less obvious factors include battlefield “friction,” fog of war, and just systems not working as expected. When these happen (and they do, e.g., Mogadishu), “system” robustness will then be the default judge of force effectiveness. Thus, by our analysis, although standoff firepower has clear value, it would be one piece of a larger maneuver-based Joint operation. This

maneuver operation can be enhanced with full-dimensional protection (insertion and combat) and focused logistics (for greater deployability and sustainment).

CONCLUSIONS

As the U.S. moves toward defining and ultimately fulfilling some of the ideas within *JV 2010*, and more precision engagement capabilities become available, it became apparent in our scenario that standoff capabilities would play a key role. All of the operational concepts we considered involved maximum use of this capability. The critical elements of the technology are in place³⁵ to carry long-range precision fires well into the future. However, we found that precision engagement by itself has key weaknesses, many of which cannot be overcome in certain situations. Technology may be able to offset or reduce the impact of some of these; however, development time and cost may be nontrivial. More importantly, some weaknesses/limitations may not be resolvable with new technologies, regardless of cost. Accounting for enemy behavior, precision standoff engagement appears to be easily countermeasureable, specifically in difficult terrain. Although we can envisage some counter-countermeasures (e.g., use of persistent, loitering weapons, update-in-flight of munitions, employment of mines), it is not apparent how effective these will be.³⁶ Thus, caution and hedging are very desirable. Although there are also risks to and countermeasures against use of small ground force maneuver units of the class we examined, having a mix of long-range fires and such maneuver appears to be quite beneficial from a mission success perspective.

For the ground maneuver capabilities we explored in this work to become viable, some key capabilities would have to be implemented. One major limiting factor was the nature of the ground force itself. Current quick-reaction ground forces (consisting mostly of dismounted infantry) can be deployed quickly, but without adequate maneuver capability, their mission scope is very constrained. More specifically, such forces can defend terrain but can also be bypassed or attacked with few options for response. Adding more maneuverability/agility to such quick-reaction forces, demonstrated clear payoff in our work. A quick-reaction force equipped with agile maneuverability, could set up ambush points and pursue or attack an enemy that opted to bypass. In the case where the enemy chooses to engage, the quick-reaction force could opt to disengage with its greater agility, and re-engage at a time and place of *its* choosing; this became especially attractive with higher levels of RSTA & C2 capability.

As noted before, aggressive levels of SEAD or, better JSEAD, or some other way to counter a range of air defenses would be required to deploy such a ground force.³⁷ Also, given that tactical agility requires the use of combat vehicles, a viable means for quickly deploying this force would be needed (both intertheater and intratheater mobility, with emphasis on the latter). Perhaps, the C-17 can provide some capability for intratheater mobility. However, even with a extensive use of C-17s, only small numbers of traditional mechanized (heavy) forces would be

³⁵ However, capabilities to detect, track, and identify dismounted enemy forces and to perform battle damage assessment are not yet in hand, and may be difficult to achieve in this time period.

³⁶ It is envisioned that dismounted enemy forces in foliage and urban areas, and information warfare systems targeting information networks will be particularly difficult to counter-countermeasure.

³⁷ Currently, SEAD can take many days to perform, precluding the immediate positioning of ground forces behind enemy lines.

quickly deployable, perhaps at too high a risk.³⁸ Thus, one other possibility is to rethink how ground vehicles might be reconfigured for quick-response, through early planning and consideration of how they might integrate, from a system perspective, with future intratheater lifters (e.g., C-130J, super short takeoff and landing (SSTOL) aircraft, and other emerging concepts).

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³⁸ In addition to providing intertheater lift, the C-17 was developed with the intent to provide intratheater lift capability; however, current planning suggests that the aircraft now will not be used in this way.

ABBREVIATIONS

AAA	Anti-Aircraft Artillery
AAN	Army After Next
ADA	Air Defense Artillery
AEFOG-M	Advanced, Enhanced Fiber-Optic Guided Missile
AFSC	Armed Forces Staff College
ARG	Amphibious Ready Group
ASP	Acoustic Sensor Program
BDA	Battle Damage Assessment
C2	Command and Control
C2V	Command and Control Vehicle
C3	Command, Control, and Communications
CAGIS	Cartographic Analysis and Geographic Information System
CBT	Combat
CS	Combat Support
DARPA	Defense Advanced Research Projects Agency
DIA	Defense Intelligence Agency
DSB	Defense Science Board
DCSOPS	Deputy Chief of Staff for Operations and Plans
DFAD	Digital Feature Attribute Data
DTED	Digital Terrain Elevation Data
ELINT	Electronic Intelligence
FA	Field Artillery
FCV	Future Combat Vehicle
FEBA	Forward Edge of Battle Area
FFRDC	Federally Funded Research and Development Center
FOPEN	Foliage Penetration

FRV	Future Robotic Vehicle
FSV	Fire Support Vehicle
HPT	High-Priority Target
HUMINT	Human Intelligence
IFV	Infantry Fighting Vehicle
IRC	Immediate Ready Company
JV	Joint Vision
JSEAD	Joint Suppression of Enemy Air Defenses
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance and Target Attack Radar System
JTF	Joint Task Force Commander
LGB	Laser Guided Bomb
LOC	Lines-of-Communication
LOS	Line-of-Sight
LOSAT	Line-of-Sight Anti-Tank
MADAM	Model to Assess Damage to Armor with Munitions
MANPADS	Man Portable Air Defense System
MEU	Marine Expeditionary Unit
MLRS	Multiple Launch Rocket System
MTMC	Military Traffic Management Command
MRR	Motorized Rifle Regiment
NDRI	National Defense Research Institute
NGIC	National Ground Intelligence Center
NVEOD	Night Vision Electro-Optical Division
RJARS	RAND's Jamming Aircraft and Radar Simulation
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RTAM	RAND's Target Acquisition Model
SAM	Surface-to-Air Missile

SARDA	Secretary of the Army for Research, Development, and Acquisition
SEAD	Suppression of Enemy Air Defenses
SIGINT	Signal Intelligence
SOF	Special Operations Forces
SSTOL	Super Short Takeoff and Landing
SUO	Small Unit Operations
TACMS	Tactical Missile System
TEA	Transportation Engineering Agency
TGW	Terminally Guided Weapon
TOF	Time-of-Flight
TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine Command
WCMD	Wind-Corrected Munition Dispenser

EXPLORING FUTURE JOINT OPERATIONAL CONCEPTS

Analytic Support to the 1998 Defense Science Board

This annotated briefing summarizes one area of research that RAND performed for the Defense Science Board (DSB) to support the summer study task force on joint superiority operations. More specifically, this briefing describes the high-resolution constructive simulation effort that assessed different force concepts, as defined by: members of the DSB, the joint force community (e.g., Armed Forces Staff College), and various warfighters.

This research was conducted within RAND's Arroyo Center, Force Development and Technology Program, and National Defense Research Institute (NDRI), Center for Acquisition and Technology Policy. It was formally sponsored by the U.S. Army, Office of the Deputy Chief of Staff for Operations and Plans, and by Office of the Undersecretary of Defense for Acquisition and Technology. It was coordinated closely with GEN (ret.) David Maddox and Dr. Ted Gold, who were members of the DSB study representing the DSB in overseeing this effort.

Project Objective

- **Explore and assess joint operational concepts as defined by the Defense Science Board**
 - **High-intensity case**
 - **Quick-reaction scenario**
- **Help integrate research with higher-level DSB effort of shaping JV 2010**

The primary objective of this research was to quantitatively assess some joint concepts of operation consistent with Joint Vision (JV) 2010 that might be viable around the 2010–2015 time frame. Although the DSB task force was asked to explore joint operations from a very broad perspective (see Terms of Reference), including low-, mid-, and high-intensity operations, the scope of this work was limited to only the high-intensity case. It was envisioned that by exploring joint operational concepts, albeit within the context of a relatively narrow solution space, useful insights would emerge.

Four Emerging Joint Vision 2010 Operational Concepts Rely on Information Superiority

- ***Dominant maneuver***—multidimensional application of information, engagement, and mobility capabilities to position and employ dispersed joint forces to accomplish operational tasks
- ***Precision engagement***—use of system-of-systems capabilities to locate an objective or target, provide responsive C2, generate desired effect, assess level of success, and retain flexibility to re-engage
- ***Full dimensional protection***—control battlespace to ensure freedom of action during deployment, maneuver, and engagement, while providing multi-layered defenses
- ***Focused logistics***—fusion of information, logistics, and transportation technologies to provide rapid crisis response, to track and shift assets even while en route, and deliver tailored logistics packages and sustainment

Four operational concepts that represent the backbone of JV 2010 include: dominant maneuver, precision strike, full-dimensional protection, and focused logistics. Information superiority is defined as a critical capability, which will help to enable the four concepts in the future. Although these concepts provide overarching guidance for shaping a joint force for the future, they provide enough flexibility for many interpretations. Perhaps this was by intention.

We planned to examine one possible set of interpretations of these joint operational concepts within a very specific scenario and situation. By doing so, we hoped to start a much-needed dialogue on what JV 2010 might mean from an implementation perspective and how defense decisionmakers might respond to activate some of the ideas within it.

Research Questions (RAND High-Resolution Analysis)

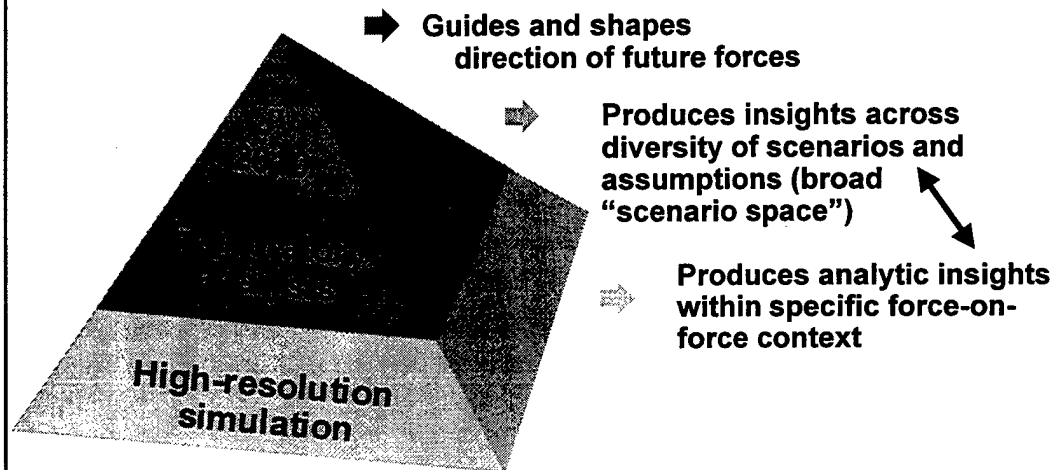
- **How can improved decision making (via RSTA and C2 capabilities) enhance future Joint operations?**
- **How should we think about the relationship between maneuver and firepower?**
- **What are the major factors affecting Joint force effectiveness?**

Key questions that the DSB asked RAND to address delve into two specific areas. First, we were asked to examine the possible impact of information superiority on future joint operations. Noting that information superiority is a relatively broad term, we broke it up into two distinguishable, assessable components—reconnaissance, surveillance, and target acquisition (RSTA) capabilities and command and control (C2) capabilities (with communications implicit).

Second, we were asked how improvements in RSTA and C2 might affect future maneuver and engagement capabilities and, as a result, how they should be changed to exploit information superiority. We note that there considerable work has been done on engagement, and in the wake of the Persian Gulf War, there is the perception that engagement has outpaced other aspects of warfare (e.g., the critical factor is no longer firepower, but rather the ability to direct it). There also is the perception that maneuver, as essential as it is seen to be, is too difficult to assess with today's analytic tools and, therefore, does not generally get assessed properly.

The third question represents an open-ended request that we consider and raise as many as possible implications of actions or conditions that could impair force performance. These may include enemy countermeasures, environmental conditions, or even poor decision making.

This Effort Focuses on “High-Res” End of Analysis



Although our work began by focusing on a detailed examination of joint operational concepts using high-resolution, constructive simulation, this work was later integrated (to the extent possible given the time available) with a more more exploratory multi-resolution approach suggested by recent RAND research.¹ This work supports the DSB from a broader perspective, examining larger scale issues. This in turn was used by the teams to help with the higher level tasks of shaping JV2010. Results from the RAND exploratory work will be published separately.² A summary integration is included in Vol. 2 with the Team C report.

¹ See RAND Issue Paper, *Transforming the Force: Suggestions for DOD Strategy*, P. Davis, D. Gompert, R. Hillestad, S. Johnson, 1998.

² Reference to RAND research, *Exploratory Analysis of Future Joint Operational Concepts: Analytic Support to the 1998 Defense Science Board Study*, (forthcoming).

Outline

- **Scenario**

- **Approach**

- **Results**

- **Insights**

This annotated briefing is divided into four major sections. In this first section, we describe the scenario for which joint operational concepts will be conceived and assessed. Next, we describe our analytic approach using high-resolution simulation. We will then summarize our interim results and finish with a discussion of emerging insights and future directions.

Motivations for Scenario Adopted

- **Interest in examining deep attack operations with:**
 - **Relatively shallow battlespace**
 - **Mixed terrain**
 - **Early “offensive” ground-force operations**
- **Examining issues for which detailed simulation is particularly important**
 - **Value of RSTA and improved decision processes**
 - **Feasibility and effectiveness of alternative operational concepts and weapons**
 - **Synergism of long-range fires and maneuver with small precision-fire forces**
- **Practicalities: available databases, leveraging ongoing research**

**Getting away
from Desert
Storm revisited**

With the limited time available for this analysis, we chose to focus on a single scenario. The particular one used was selected because it was stressing, it exercised all the aspects of JV 2010, and it was available from an ongoing Army research effort.

The scale and topography lent itself well to deep attack operations. The battlespace is, by some interpretations, relatively shallow (several hundred km), yet large enough to encourage joint operations and elements of maneuver. The terrain is also sheltered enough to provide cover for an advance, unlike Desert Storm.

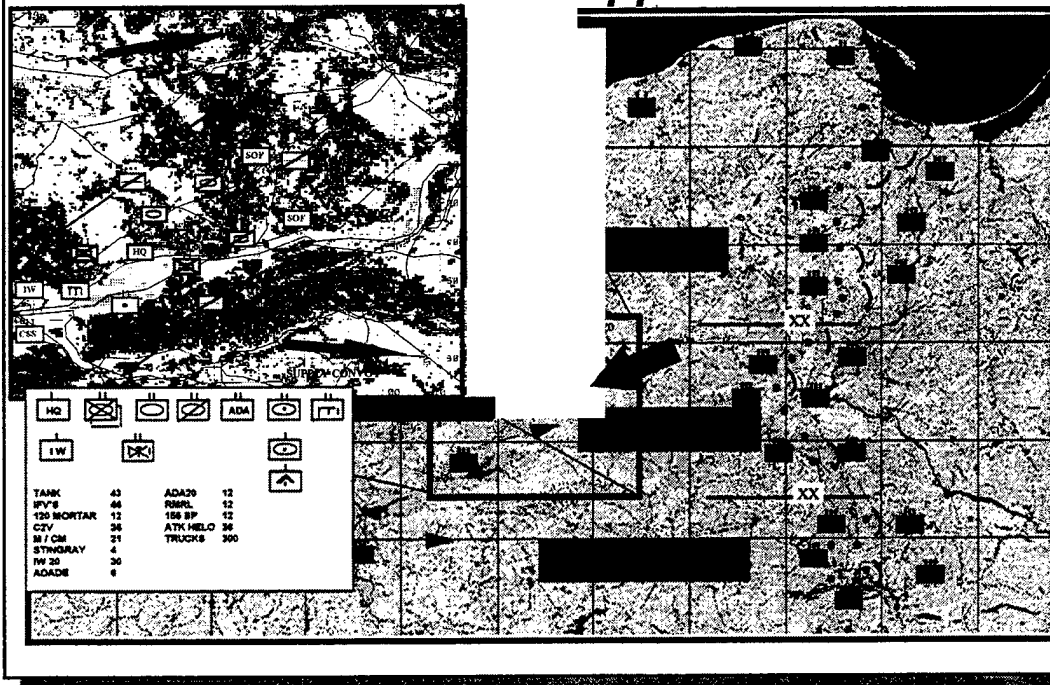
Objectives and Strategy Assumed for Analysis

- **Friendly force objectives—quickly stop enemy advance, weaken his forces, and gain initiative**
- **U.S. application of Joint force**
 - **Establish theater defenses, support allies with liaison teams, conduct SEAD, conduct strategic bombing,...[not simulated here]**
 - **Apply variety of long-range fires immediately**
 - **Attack into enemy's rear almost immediately to help cause attrition, break momentum, and seize the initiative**

The scenario and situation that we proposed to examine future joint operational concepts is described over the next several charts. First, we stipulate that this scenario is a highly stressing one for the U.S. It is representative of a difficult, quick-reaction situation in which U.S. forces are committed to respond to an aggressive threat in the 2010–2015 time frame. Generally, it requires the U.S. to establish control throughout the depth of the battlespace and to quickly regain the initiative at the operational level. This begins with a series of actions that are not modeled and are assumed to be successful—linking up with the coalition forces, carrying out suppression of enemy air defenses (SEAD) operations, and gaining air superiority. The application of Joint force we examine in detail consists of a combination of standoff, long-range fires, and operational maneuver.

Although the scenario is hypothetical, we used an existing digital database for mixed terrain (East Europe) and we consulted various organizations such as the Defense Intelligence Agency (DIA) and the National Ground Intelligence Center (NGIC) to help us shape a notional adversary's capabilities, composition, and application of force in this time frame. The next chart will describe the scenario and U.S. mission in more detail.

U.S. Mission: Deny Enemy's Ability to Form "Critical Mass" to Support Advance

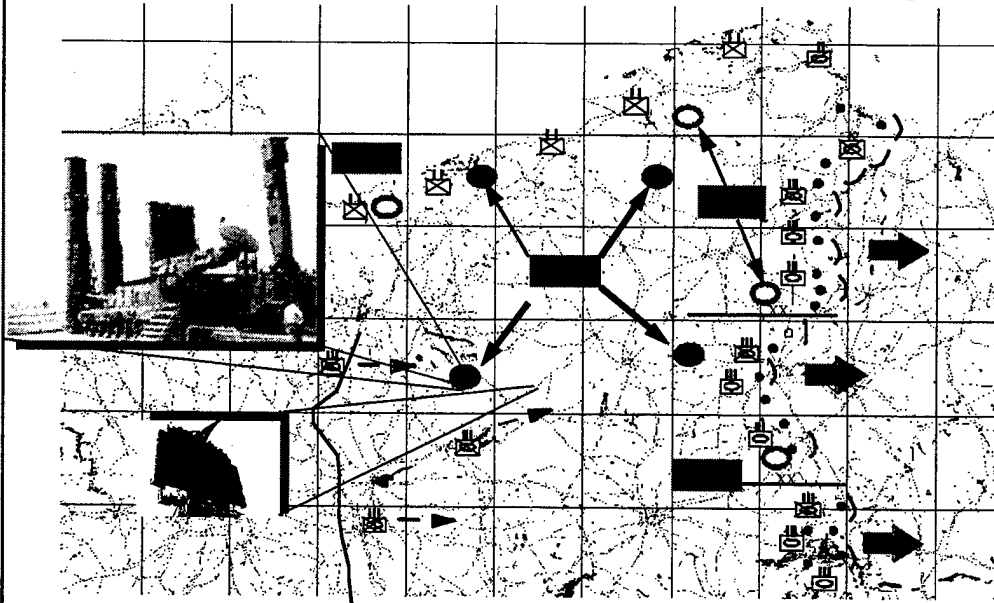


The situation shown above is about five days into the enemy advance. The enemy mechanized units have been slowed by what might be considered a conventional coalition defensive force. (The area of engagement shown above is several hundred kilometers on a side, with grid lines shown at 50 km in the image.) The mission of the U.S. forces requires the rapid establishment of control at depth within the battlespace. More specifically, the assumed U.S. operational mission is to stop the elite enemy division, starting with the lead regiment (shown by the insert) that is *en route* to providing reinforcement to the salient shown above.³ There is an element of urgency in this situation. It is assumed that if the elite enemy division reaches the front at strength it will have the power to rupture the line of the U.S. ally. Opportunities to engage the enemy are limited, however, due to the mixed, foliated terrain.

Success in this scenario requires the U.S. to project power very quickly well behind enemy lines. Although this would likely be implausible with today's forces and associated capabilities, it is envisioned that through a combination of maneuver (strategic, operational, and tactical), precision engagement, full-dimensional protection, and focused logistics, in conjunction with new or enabling technologies, a set of possible "solutions" can be identified.

³ The U.S. forces could operate conventionally, helping to shore up the coalition defense by establishing a safe haven offshore in the northeast and deploying additional heavy forces and air power. Unfortunately, this would require excessive time for build-up, and the coalition force is near breaking.

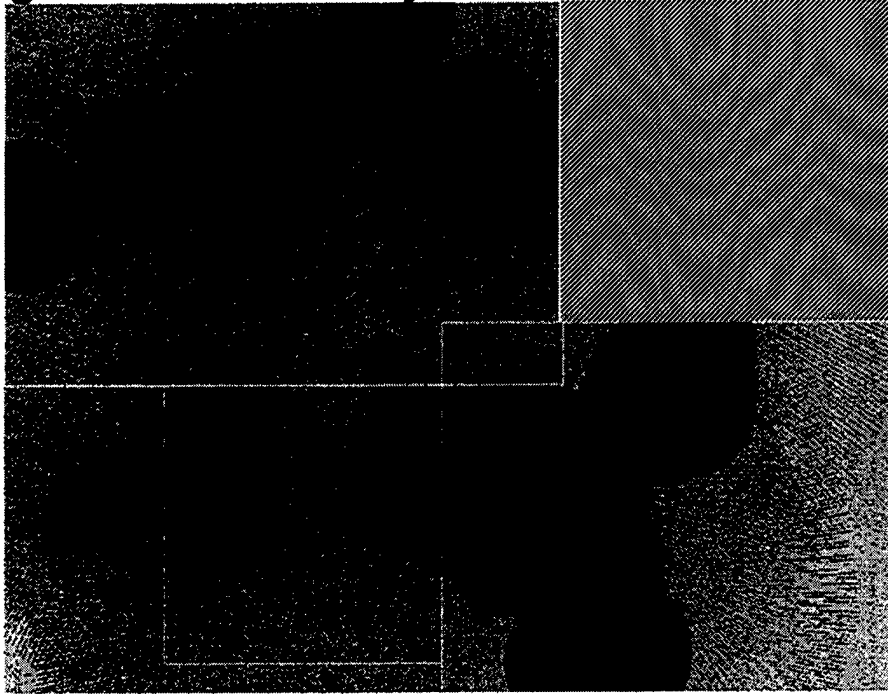
An Integrated Air Defense Network Is One of the Enemy's "Asymmetric" Strategies



One asymmetric strategy that a future threat is likely to employ to counter U.S. air power is a sophisticated integrated air defense network. For our threat, we presume that long-range, high-end systems such as Russian SA-12s and SA-17s are emplaced throughout the depth of the battlespace. Since these are relatively mobile, tactical surface-to-air missiles (SAMs), they can accompany the advancing mechanized formation. In addition to these long-range systems, we include medium-range systems including SA-15s and short-range systems such as 2S6s, SA-18 man-portable air defense systems (MANPADS), and anti-aircraft artillery (AAA) in the network.

Although these air defenses operate in a stand-alone mode and can be quite formidable, they can become a significantly greater challenge when integrated. More specifically, these air defenses are represented as "partially integrated" in our simulation. A number of early-warning radars (both air- and ground-based) are emplaced throughout the depth of the battlefield. These systems can provide cueing to the SAMs, allowing the SAMs to remain quiescent and, thus, making them more difficult to find. In some cases such as the MANPADS, which tend to be passive systems, it is unlikely that their locations will be known in the 2015 time frame.

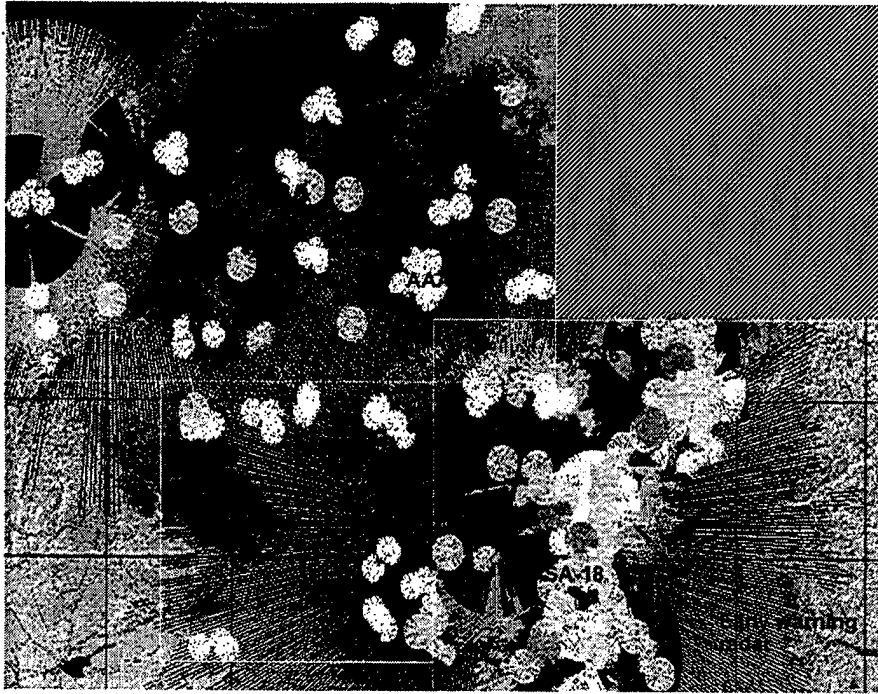
High-Altitude Enemy Air Defense Coverage



The above chart depicts the enemy air defense coverage patterns at medium altitude, approximately 20,000 ft. The long-range early-warning radar coverages are shown in blue and purple, SA-12s are shown in green, and SA-17s are in yellow. The medium-range SA-15s (shown in red) cover the areas over the coast and the enemy front line. The region in the northeast is not considered here, as it is assumed to be covered by an adjoining enemy unit.

Attacking and taking down at least part of this integrated air defense network appears to be a necessary first step. There are a number of methods by which this can be accomplished today; however, the enemy is likely to take steps to protect this asymmetric strategy well into the future.

Low-Altitude Enemy Air Defense Coverage



In contrast to the previous chart, this one shows the coverage pattern of the same air space but at much lower altitude, approximately 100 ft. Here, it is evident that the coverage of the long-range systems is substantially reduced because of line-of-sight (LOS) limitations. Nonetheless, even with reduced coverage, the overall numbers of systems to contend with, resulting in considerable redundancies of coverage, can be overwhelming to a pilot attempting to penetrate air space at this altitude.⁴

Drawing on previous analysis, the density and lethality of the enemy air defenses in this scenario will likely require a combination of SEAD, reduced airframe signature, and special flight profiles to ensure survivability. In all of the concepts we examined, we intended to separate the SEAD issue from those that we addressed. Thus, survivability in this enemy airspace was assumed.

⁴ Number, density, and placement of air defense units shown here were coordinated with representatives of both DIA and NGIC.

Outline

- **Scenario**

- **Approach**

- **Results**

- **Insights**

This next section describes the basic research approach we used:

Three Critical Steps of This Research

- **Parametrically define different RSTA & C2 capabilities**
 - Low, mid, and near-perfect at operational level and below
- **Define joint operational concepts (firepower and maneuver)**
- **Analyze effectiveness of concepts**
 - Interactive force-on-force assessment

Enemy force capabilities kept constant (force design, organization, and support capabilities)

As noted previously, the two key dimensions of JV 2010 we are exploring are (1) the impact of RSTA and C2 on joint force decisionmaking quality, and (2) the importance of maneuver and engagement to these quick-reaction forces. The first dimension was examined parametrically, with values ranging from current (low) levels of information completeness, timeliness, and discrimination, up to a near-perfect bounding case, in which the commander has a complete and up-to-date picture of his own and the enemy's situation.

The second dimension varied the maneuver component, from a pure standoff attack operation using air power and standoff missile fires, to use of standoff attack complimented by deep insertion of ground forces. The first ground maneuver option (case 2) was an evolutionary one, proposed by representatives of the XVIII Airborne Corps and instructors at the Armed Forces Staff College. Here, the joint forces would establish a beachhead enabling a single combined arms maneuver battalion to be deployed and present a threat against the enemy elite units. This case 2 force was assumed to be armed with systems already projected in the Services' POMs. The other ground options (cases 3 and 4) were more revolutionary, and more in keeping with notions of the DSB. Here, agile, dispersed ground components would be quickly inserted deep and would strike and maneuver against the vulnerable components of the elite units.

Defining RSTA and C2 Capabilities, Parametrically, by Their Components

Assumed RSTA capabilities

- **Low-level**
 - Coverage foliage/open: 0/40%
 - Accuracy*/discrimination: 200m/detect
 - Latency/update interval: 5 min/cont.
- **Mid-level**
 - Coverage foliage/open: 20%/70%
 - Accuracy*/discrimination: 100m/recognize
 - Latency/update interval: 1min/cont.
- **Near-perfect (*bounding case*)**
 - Coverage foliage/open: 100%/100%
 - Accuracy*/discrimination: 1m/identify
 - Latency/update interval: real time/cont.

C2 capabilities

- **Nominal**
 - Fusion: 100%
 - Delay: 30 min
- **Fast**
 - Fusion: 100%
 - Delay: 5 min
- **Instantaneous**
 - Fusion: 100%
 - Delay: none

**Assumption:
canopied roads**

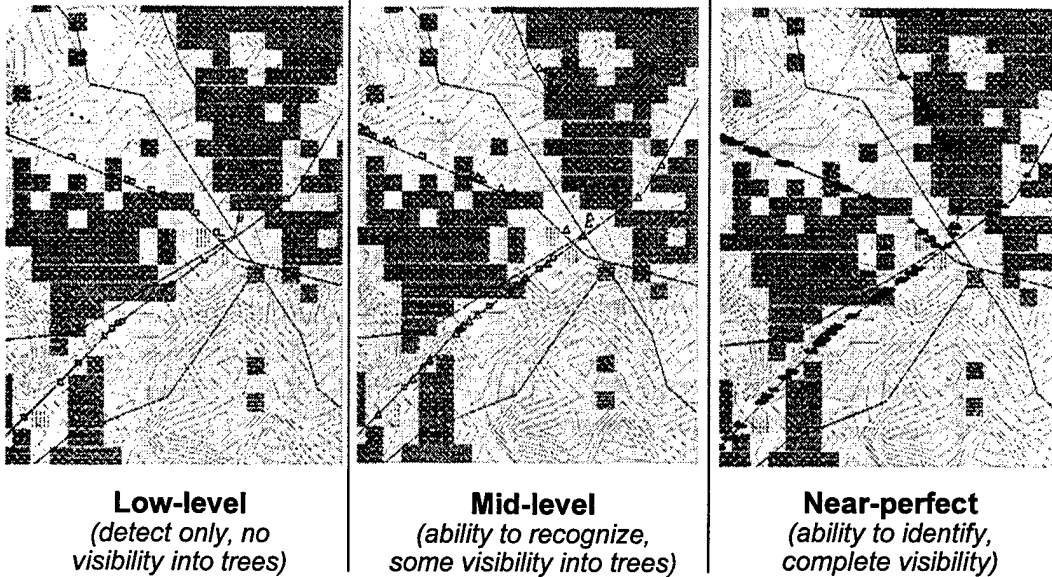
*Since enemy movement is along road, correlation was assumed

RSTA and C2 capabilities tend to result from interactions of many factors, such as search areas and sensitivities of overhead assets such as the Joint Surveillance and Target Attack Radar System (JSTARS) and satellite sensors; inputs from signal intelligence (SIGINT); electronic intelligence (ELINT), and other indicators collected from air and ground platforms; degradations due to communications-relay delay times and losses, and effects of weather, terrain, and countermeasures. For simplicity in this short study, we postulated three parametric levels for RSTA and C2 capabilities, established by expert consensus, allowing us to roughly assess the importance of improvements in each of these.

The lowest level of RSTA was set to be conservative. No foliage penetration was assumed, about 40% of targets in the open could be detected and located but not recognized, and the time from detection to receipt of the information at the command center is five minutes. It should be noted that that enemy vehicles passed through many canopied areas even while they were on roads. The mid level improves the low level to 20% foliage penetration (FOPEN), 70% in open, recognition rather than detection only, and time of receipt drops to one minute. The near-perfect case was instituted to determine the extreme case—complete coverage at high accuracy, discrimination, and timeliness.

Command and control capabilities also started low, with a 30-minute delay for processing the information, deciding how to engage, and passing commands to a shooter. Fly out times are additional to this. The mid level drops the C2 delay to 5 minutes, and the bounding case has no time delay.

Representation of Different “RSTA” Levels in Constructive Simulation



These three images illustrate the differences in situation awareness with the three parametric levels of RSTA. The low-level case shows a portion of the enemy vehicles and does not differentiate them by type. The mid-level case shows more vehicles and categorizes them as track or wheel. The near-perfect case identifies all the vehicles and locates them precisely.⁵

⁵ While difficult to see in this figure, a full-scale screen shot for the near-perfect case would show distinct icons for each type of vehicle. The mid-level case differentiates tracks and wheels with triangles and circles, and the low-level case simply indicates contacts with squares.

Operations Involve Extensive Use of Standoff Capability with Varying Levels of Maneuver

- **Case 1: Standoff Joint fires**
- **Case 2: Standoff Joint fires with ground insertion for blocking**
 - 1 Infantry Bn with RFPI-level of improvements
 - 2 IRCs (M1s and M2s)
- **Case 3: Standoff attack with agile ground maneuver attacking reinforcing division (attrition focus)**
- **Case 4: Standoff attack with agile ground maneuver attacking soft rear-area targets (disruption focus)**
 - In 3 and 4: 10 teams of “SARDA mobile strike force” (FCV, FRV, and FSV) as surrogates for diverse Marine- and Army-concept forces

The four operational concepts we consider are quite distinct in their level of maneuver and type of force application (all cases rely heavily on the aggressive use of standoff attack). Case 1 concentrates solely on standoff attack using B-2 and F-15-delivered JSOW, along with Navy and Army versions of TACMS. These attempt to stop the advance of the elite enemy units.

Case 2 adds the insertion of a consolidated force (an advanced infantry battalion with two immediate ready companies (IRC)s) to the standoff fires. This insertion requires establishing a lodgment and securing airfields for C-17s. Once in, the force flanks the enemy unit. The hope is that the enemy force will perceive this as a serious threat and turn to attack in response, thus detracting from the enemy's primary objective of reaching the forward line of own troops (FLOT).

Case 3 changes the picture to one of dispersed U.S. forces inserted deep to disrupt and attrit the enemy force at many points. This concept is one shared in many ways by USMC's Hunter Warrior, DARPA's small unit operations (SUO), TRADOC's AAN and Mobile Strike Force, and SARDA's Alternative Medium Weight Strike Force. The SARDA-defined force was the one we chose to use in this analysis. We employ a small ten-team force using three of the seven types of vehicles specified in the SARDA concept, described in more detail later.

Case 4 varies from case 3 only in application of force. Instead of using the agile maneuver forces against the enemy's combat forces, these forces concentrate on the “softer” logistics and supply vehicles.

General Features of Joint Concepts

- **JSEAD (not simulated here)**
- **Standoff fires (AF and Navy JSOW, and both Army and Navy TACMs) (simulated in some detail with human in loop for force-employment tactics versus sensible enemy regimental tactics)**
- **Insertion of ground-maneuver units (gamed as function of RSTA to assess subjectively feasibility and ability to find ambush sites or soft rear-area targets)**
- **Engagement of targets by ground-maneuver units (simulated)**

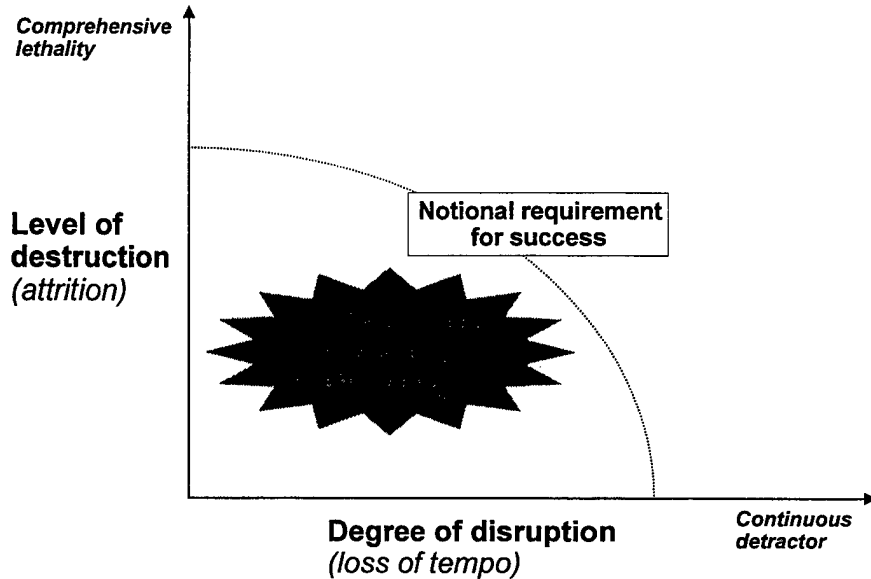
Each of the operational concepts we examined in this study requires a precise sequencing of events. Each of these events is accounted for (some through high-resolution simulation and gaming) differently. JSEAD and theater deployment are assumed to be successful, so we do not assess them. Standoff, long-range precision fires are modeled in detail, as are engagements between ground vehicles. Simulation of these includes quantitative characterization of sensing, movement, system delays, munitions effects, etc. Quality of insertion and extraction of ground-based maneuver units is determined subjectively for this study, based on off-line gaming.

Gaming and Simulation Were Used

Operation	Simulation?	Man in Loop?	Comment
Enemy air and missile defenses; SEAD	No	Preplanning	SAM laydown represented to affect tactics
Enemy movement tactics	Yes	Yes	Sensible, dispersal, "packeting," use of minor roads
Standoff attack with PGMs	Yes	Yes	Targeting dependent on RSTA
Insertion of ground maneuver units	"Yes"	Preplanning	Sensible ambush sites, movement, extraction
Engagement by maneuver units	Yes	Yes	Targeting dependent on RSTA
Extraction	Yes	Preplanning	Survival simulated

More specifically, each of the phases of operation was simulated using a different combination of man-in-the-loop reactive actions or preplanned (scripted) responses. Enemy and U.S. force actions were planned and executed independently, by different members of the simulation team. These actions were affected by the degree of RSTA provided and the C2 delays assumed. As mentioned, suppression of enemy air defenses (SEAD) is assumed in this analysis. The amount of resources and time required to reduce enemy air defenses to an acceptable level could, however, be a very significant influence on U.S. ability to execute any of the four cases explored in this analysis.

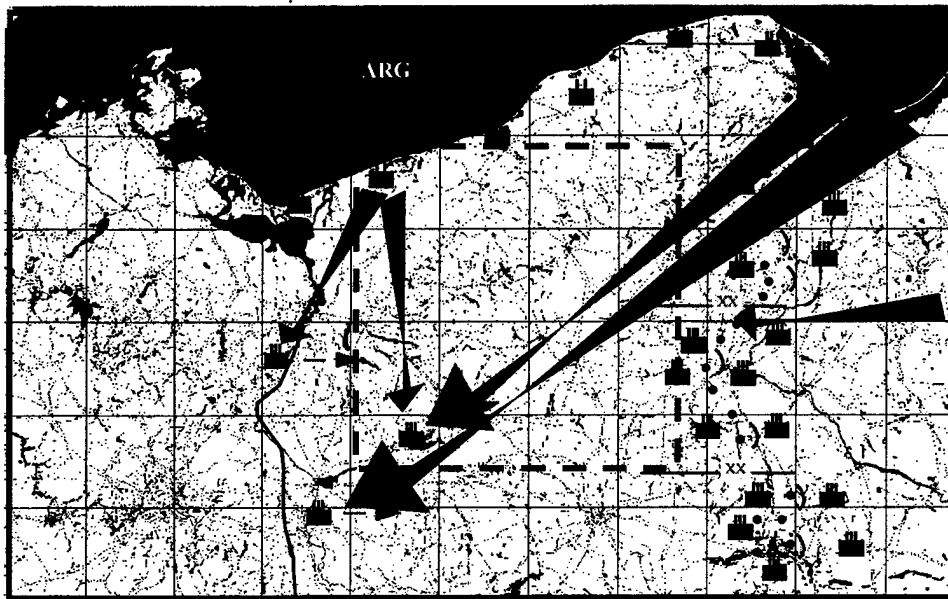
Effectiveness Can Be Gauged by Level of Destruction or Degree of Disruption



Assessments usually concentrate on enemy attrition (and own losses) as the primary measure of effectiveness (MOE), even though the dynamics of this engagement are such that disruption of the enemy operation—denying him the ability to move or resupply, slowing his progress, dispersing his forces, or degrading his coordination capabilities—may be as important as attrition. Shock effects (heavy losses over a short time, in small areas, or of key systems) may also disrupt the advance.

We will attempt to characterize the outcomes of the scenario along two dimensions—level of destruction and degree of disruption. As shown by the dotted curve in the figure above, many different combinations of these two factors may be sufficient to change enemy behavior. Success criteria for this curve tends to be subjective in nature.

Case 1: Standoff Attack Operation

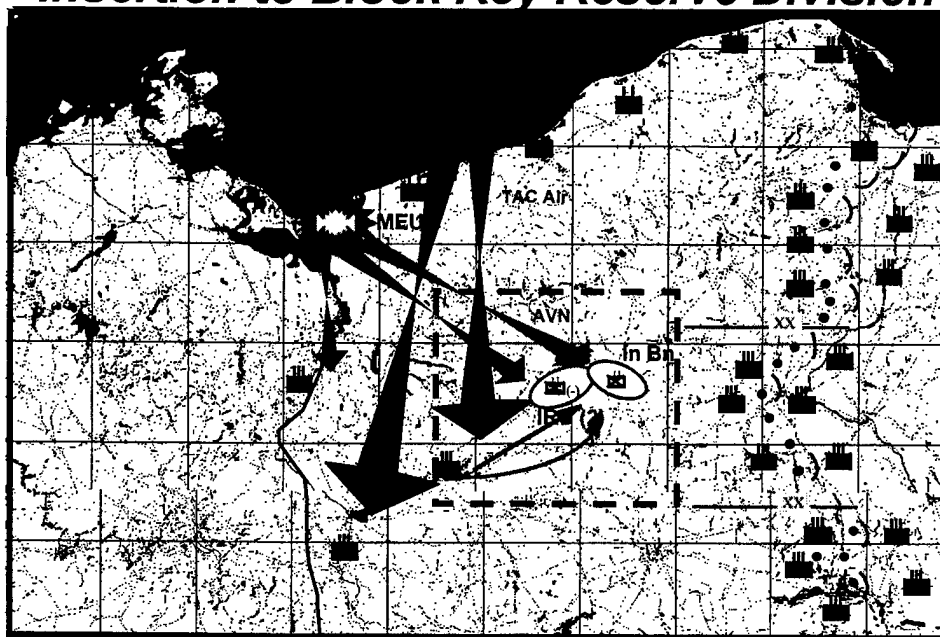


The stages of case 1 are delineated here. Generally, a joint-SEAD (JSEAD) operation aided by Special Operations Forces (SOF) opens air corridors to the target units. Army aviation is used to bolster the coalition defense along the FLOT. Naval missile fires from the amphibious ready group (ARG) concentrate on the lead and northern enemy units, while air strikes (B-2 and F-15 with JSOW) attack the lead and southern units. The primary objective is to attrit the units sufficiently so that they cannot close with the units in contact.

Specific phases of the battle plan:

- U.S. Air/Helo/Ground assets combined with coalition SEAD to open air corridor(s). SOF inserted to provide human intelligence (HUMINT) and battle damage assessment (BDA).
- Army attack helos destroy motorized rifle regiment (MRR) in center TD along FLOT. U.S. infantry conducts infiltration in support along with limited air support and field artillery (FA). Marine expeditionary unit (MEU) seizes beach on north coast. U.S. air attacks to attrit and slow lead and northern MRR (priority to lead).
- MEU attacks to defeat northern MRR. U.S. air shifts priority of attack to defeat southern MRR (80%) and continues to attack lead MRR.
- MEU continues attack on northern MRR. Air attack continues against southern MRR.

Case 2: Standoff Attack and Ground Insertion to Block Key Reserve Division

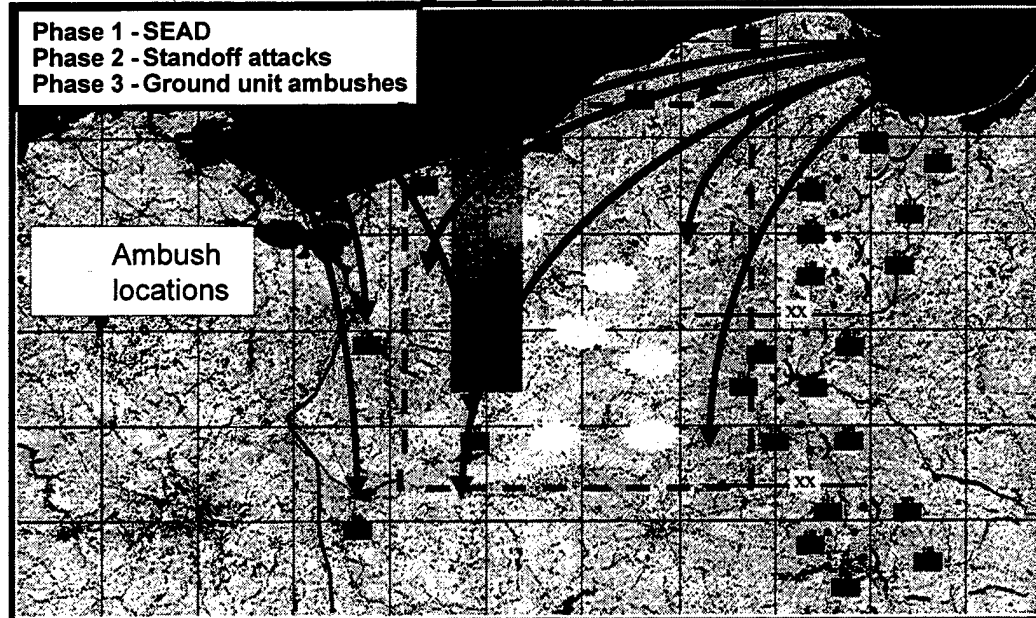


Case 2 also carries out the JSEAD and standoff attack missions, but adds the insertion of a cohesive ground force. The ground force is made up of MEU and an airborne infantry battalion augmented with future systems such as EFOG-M, LW-155, Outrider, and ADAS. The airborne battalion is augmented by two Immediate Ready Companies (IRCs), which each have 4 M1s and 4 M2s (deployed with C-17s). The MEU first establishes a lodgment at the coast, enabling the Army ground force to be inserted to the flank of the lead elite enemy regiment. By enhancing its apparent size with deception devices, the IRCs try to provide a sufficient threat to turn the lead regiment. If successful, they use a combination of fire and maneuver to try to attrit and disrupt the enemy attack.

Specific phases of the battle plan:

- Begins with JSEAD and SOF insertion. Air begins attrition of lead MRR. MEU lands to establish lodgment and FARRP to north. IRC expands lodgment.
- ABN battalion establishes battle position north of lead MRR route of advance. IRC maneuvers to flank lead MRR.
- Combination of ground, rotary, and fixed-wing air attack MRRs to delay and then defeat.
- This creates a dilemma for the enemy commander by threatening his operation with a ground unit capable of physically interdicting lines of communications (LOCs) and destroying combat units.

Case 3: Standoff Attack and Agile Ground Maneuver To Engage Key Reserve Division



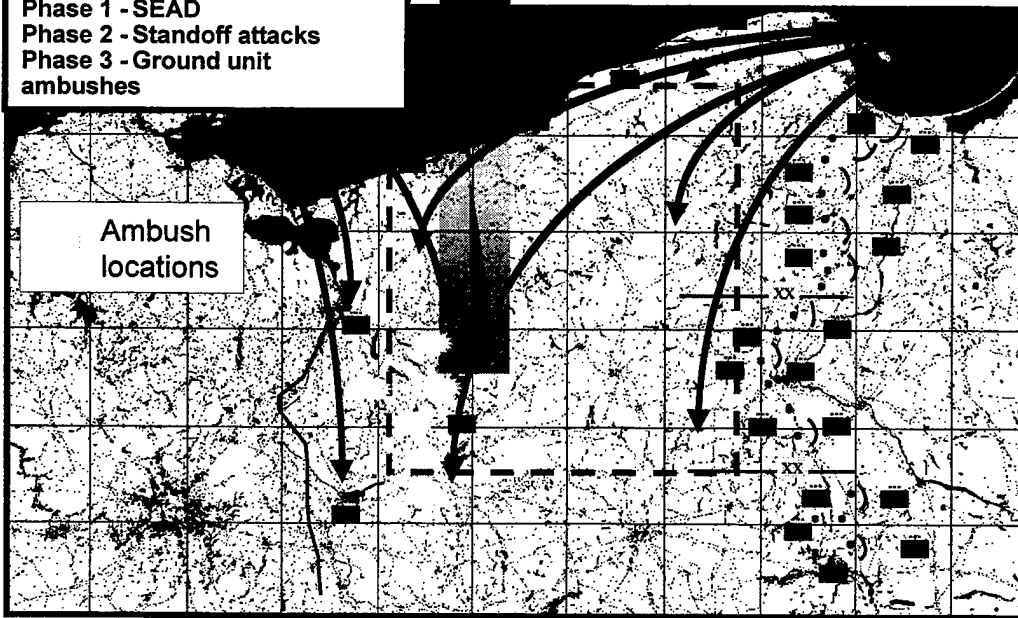
In case 3, standoff attack and quick-deploying maneuver forces are used to attrit and disrupt the enemy operation at many points. The JSEAD operation hits air defense sites throughout the region, and at the same time cuts a corridor through for an insertion. Standoff attacks target all of the elite units, while the ground units are deployed along the enemy's routes of advance. The ground units set up ambushes and plan for egress routes to their next attack points. Three types of enhanced medium-weight vehicles are used: future combat vehicles with LOSAT direct fire KE systems, fire support vehicles with advanced (30 km) fiber optic guided missiles, and robotic vehicles that can call in fires during the ambush and in the egress phase, in which they may be left behind. All of these systems can be airlifted by C-130s.

Specific phases of the battle plan:

- U.S. Air/Helo/Ground assets combined with coalition JSEAD to open air corridor(s). SOF inserted to provide HUMINT and BDA.
- Long-range standoff attacks conducted by Joint Task Force assets (both aviation and artillery).
- Light, highly maneuverable ground force conducts direct-fire ambushes to destroy the lead regiment.
- Air attack continues against northern and southern MRRs.

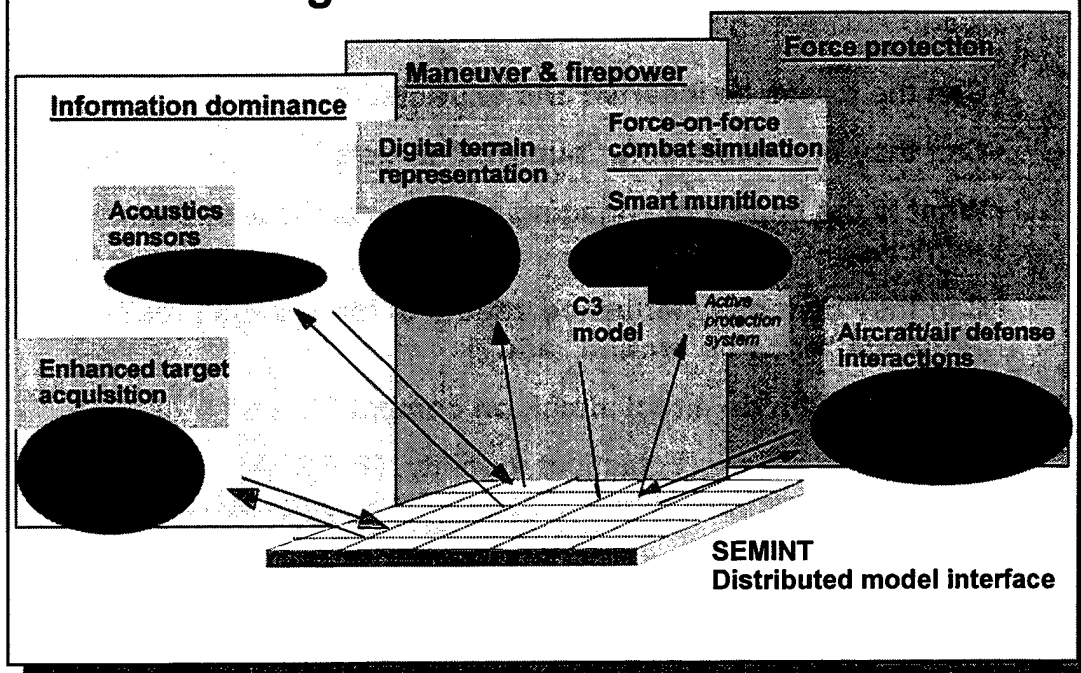
Case 4: Standoff Attack and Agile Ground Maneuver To Engage Deep, Soft Targets

Phase 1 - SEAD
Phase 2 - Standoff attacks
Phase 3 - Ground unit
ambushes



Case 4 appeared to be of greater interest than the other cases to the DSB. As in case 3, very agile ground maneuver forces are inserted to stop the deep elite enemy unit. However, the position of these forces is further to the west to directly engage the logistics and supply vehicles (more specifically, these include resupply trucks, C2 vehicles, self-propelled artillery units) which in this scenario, because of the great levels of dispersion, follow well behind the lead combat units. These “softer” targets are seen as being highly desirable targets, since any engagement of these forces would likely create havoc for enemy movement while minimizing the risk of the attacking U.S. force (since these enemy units have substantially less combat power). However, because the agile U.S. forces will need to get past the enemy combat units, to get to these soft targets a certain level of “stealthiness” is required.

Research Approach Involves Application of High-Resolution Simulation



The basic models we used are shown above. Generally, they include a force-on-force combat model (Janus) with several “attached” models such as MADAM (Model to Assess Damage to Armor with Munitions, a model for simulated emerging smart and brilliant munitions), a C3 model (for better assessing the impact and degradations of C3), and a newly created active protection model. Other models include: CAGIS (the Cartographic Analysis and Geographic Information System, used for enhanced digital terrain representation), ASP (the Acoustic Sensor Program, for modeling acoustic sensor phenomenology), RTAM (RAND’s Target Acquisition Model, for enhanced target acquisition techniques), and RJARS (RAND’s Jamming Aircraft and Radar Simulation, for simulated surface-to-air interactions).

We analyzed the various conditions using the high-resolution simulation tools identified above. With the exception of the broad levels of RSTA and C2 (which were simulated parametrically), each entity was represented at the system level, including individual tanks, air defenses, aircraft, missiles, etc. The scenario was set up interactively using experienced military personnel, including Janus gamers and one of our RAND military fellows. Individual excursions were then run over a large number of iterations (typically 30) to arrive at a statistically stable sample of the stochastic outcomes. Several measures of effectiveness beyond that of simple attrition were used in the analysis. In this way, some attempt was made to capture the effects of disruption, delay, and selective targeting of key assets.

For Now, Use Simulation To “Think About” Disruption In Addition to Attrition

- Can the forces be inserted and extracted?
- Can they find good, soft, “support” targets?
- What is the impact of engaging moving combat-support vehicles?
- Can they materially influence effects of long-range fires? (What do “eyes on ground” add?)
- Can they even do direct attack on combat forces?
- How important are (1) tactical mobility, (2) RSTA, (3) organic weapons, (4) long-range fire’s responsiveness?

In this study, the high-resolution simulation was not intended to provide definitive assessments of the utility of single technologies or capabilities. Rather, it was envisioned to serve as a tool for providing insights on the key aspects of future operations—the challenges of operational and tactical mobility and maneuverability, the challenges of coordinating long-range precision fires and agile ground maneuver elements, and the potential payoff for improved RSTA & C2 capabilities.

We identified earlier both level-of-destruction and degree-of-disruption as possible measures of success in this scenario. To some extent, the latter still needs to be refined. Disruption in this scenario can be as effective, and possibly easier to achieve, than destruction. The operational requirement is to prevent the enemy elite division from reaching the FLOT effectively (with the force and timing required). In this study, we use the simulation environment to help provide context for thinking about the disruption aspect of an operation, and on which enemy forces to concentrate maneuver and fires.

Outline

- **Scenario**
- **Approach**
- **Results**
- **Insights**

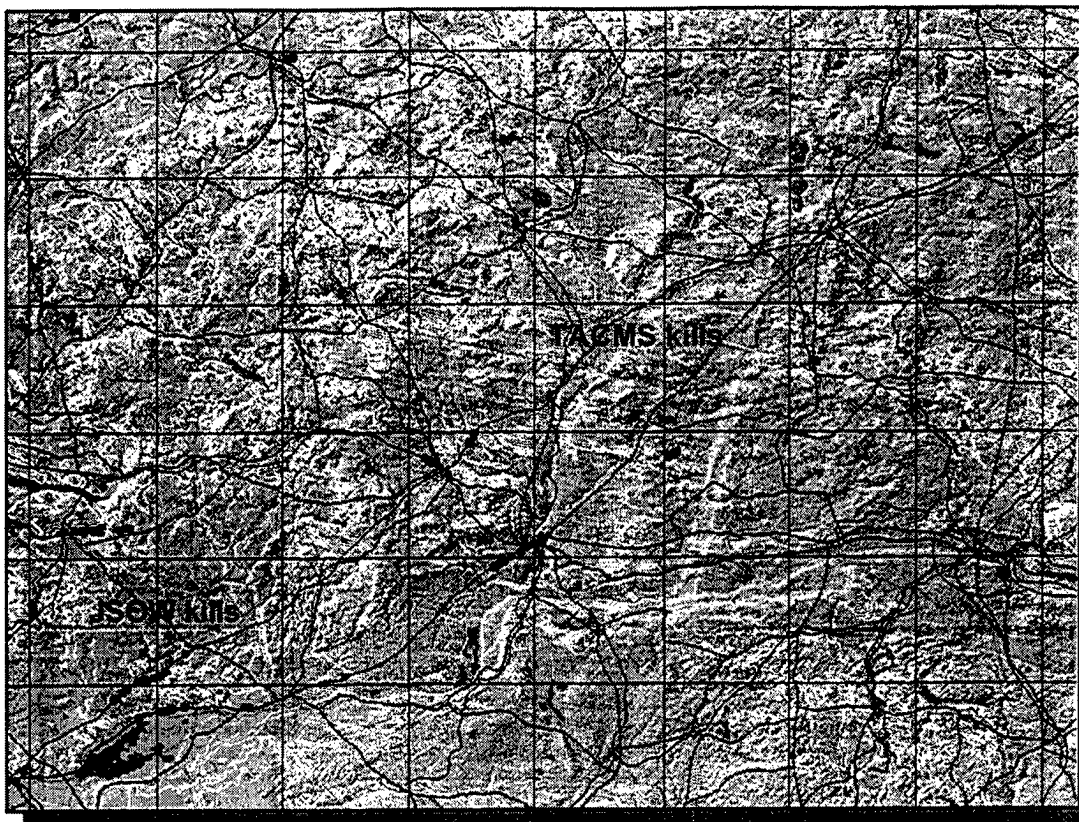
This section summarizes our findings to date.

[illegible]

- SEAD is critical part of the attack operation
- Deconfliction of airspace could result in better use of weapons
- Foliage represented a major limitation on placement/numbers of weapons
- Long cycle times (BDA) limited number of total engagements

For the standoff weapons case, the planners set up separate engagement zones for aircraft and missiles. This was done to ensure deconfliction of the assets. The aircraft launch their JSOW canisters from as much as 70 to 80 kms away, but this is still in the envelope of the long-range, high-end air defense systems. Accordingly, we assume JSEAD is successful against these emitters. The planners still have a difficult task targeting the smart munitions, as there are only limited open areas between covering foliage, and some amount of lead must be programmed into the targeting points to compensate for the weapon's long (10-minute) flyout time.⁶

⁶ We assumed a 10 minute time-on-target, which might occur when lofting a subsonic-speed dispenser from moderate standoff range. Shorter timelines would occur from more dangerous close range launches, or from up-date-in-flight capability (using comm links to the weapon).



This exemplary screen shot illustrates the cumulative locations of kills achieved by the two types of standoff weapons. The JSOW kills (shown in blue) concentrate on open areas in the southwest. TACMS kills (in red) are more spread out in the center of the engagement area, due to the smaller number of appropriate targets (loud tracked vehicles) and less predictable movements by the enemy during this interval.

CONDITIONS FOR TACMS ENGAGEMENTS

CASE 1 series	PROB (TREE)/ PROB(NO TREE)	LATENCY	BDA	C2 DELAY	TIME OF FLIGHT	TOTAL LEAD TIME	RMKS
A	0.0/0.4 (LOW)	5 MIN	NO	5 MIN	10 MIN	20 MIN	SENSOR TO HQ
B	0.2/0.7 (MED)	1 MIN	NO	5 MIN	10 MIN	16 MIN	SENSOR TO HQ
C	1.0/1.0 (HIGH)	0 MIN	YES	5 MIN	10 MIN	15 MIN	SENSOR TO HQ BDA USED
D	0.0/0.4 (LOW)	5 MIN	NO	0 MIN	10 MIN	15 MIN	SENSOR TO SHOOTER
E	0.2/0.7 (MED)	1 MIN	NO	0 MIN	10 MIN	11 MIN	SENSOR TO SHOOTER
F	1.0/1.0 (HIGH)	0 MIN	YES	0 MIN	10 MIN	10 MIN	SENSOR TO SHOOTER BDA USED

RESULTS FOR JSOW AND TACMS ENGAGEMENTS

CASE	JSOW FIRED	TACMS FIRED	JSOW CS KILLS	JSOW CBT KILLS	JSOW TOTAL KILLS	TACMS CS KILLS	TACMS CBT KILLS	TACMS TOTAL KILLS
A	144	40	33	7	40 (0.28)	2	16	18 (0.45)
B	144	60	34	6	40 (0.28)	1	19	20 (0.33)
C	144	68	33	7	40 (0.28)	2	21	23 (0.34)
D	144	40	34	6	40 (0.28)	3	29	32 (0.80)
E	144	48	34	6	40 (0.28)	1	25	26 (0.54)
F	144	68	33	10	43 (0.30)	4	32	36 (0.53)

* Each JSOW contained two submunitions; TACMS was assumed to carry multiple submunitions; numbers in parentheses represent efficiency per weapon.

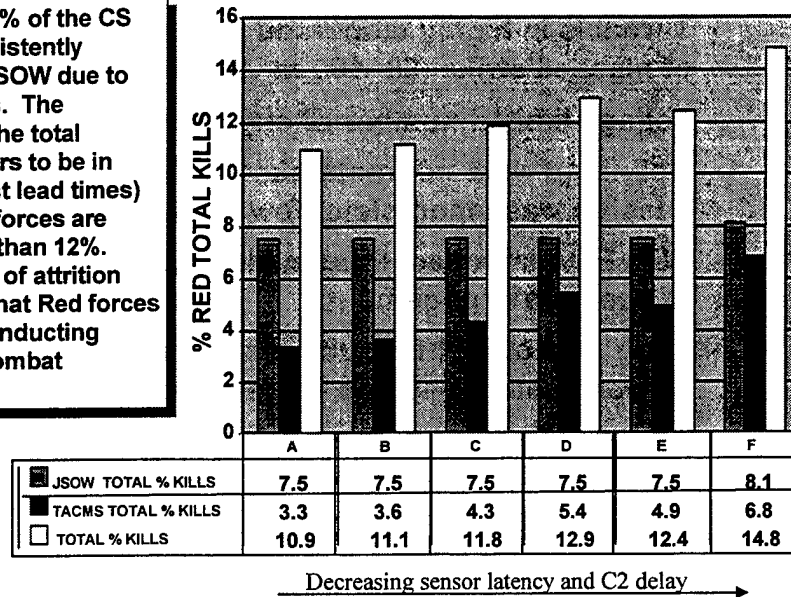
The results of six different case 1 excursions involving different levels of RSTA and C2 are shown above. Each excursion varied the level of detection probability (low, medium, and high) in both foliage and open areas. The timeliness of information (latency), engagement method decision time, and time of flight were also varied in each excursion. Only in cases of perfect information (high) was BDA (battle damage assesment) used in target planning. Here the planner observes the outcomes prior to targeting the next set of weapons.

Targeting methodology included the following steps: decide: choose location and number of missions fired based on number of HPTs (high-priority targets, consisting of six or more armored vehicles) and targets of opportunity; detect: track all HPTs or targets of opportunity for engagement in open areas along the three major avenues of approach; and deliver: fire missions into target areas with lead time calculated to interdict HPTs or targets of opportunity in open areas. Each JSOW contained 2 submunitions. Each fire mission used 2 TACMS per engagement with multiple submunitions.

Terrain and composition of target sets had a significant effect on TACMS efficiency. Advantages from better intelligence on enemy forces were hindered by the paucity of suitable target areas (open terrain) and ineffective destruction of vehicles with low acoustic signatures (CS vehicles). However, more TACMS were fired in cases with better intelligence due to the target methodology used to engage HPTs and targets of opportunity.

Overwhelming Majority of Enemy Vehicles Survive Against Standoff Attack

In all cases only 11% of the CS vehicles were consistently destroyed by the JSOW due to limited target areas. The greatest effect on the total enemy force appears to be in cases D-F (shortest lead times) when CBT vehicle forces are degraded by more than 12%. However, this level of attrition would not ensure that Red forces are incapable of conducting future MRR level combat operations.



The greatest effect on the enemy appears to be in excursions D-F (shortest lead times) when the Red combat vehicle force was degraded by more than 12%. However, although the combination of improved intelligence and shorter "lead times" significantly improved the TACMS targeting effectiveness, the level of total Red attrition due to TACMS and JSOW kills never rose above 15 %. Under the most advantageous conditions, the maximum level of attrition in case 1 was not sufficient to prevent Red forces from conducting future MRR-level combat operations and continue toward its objective.

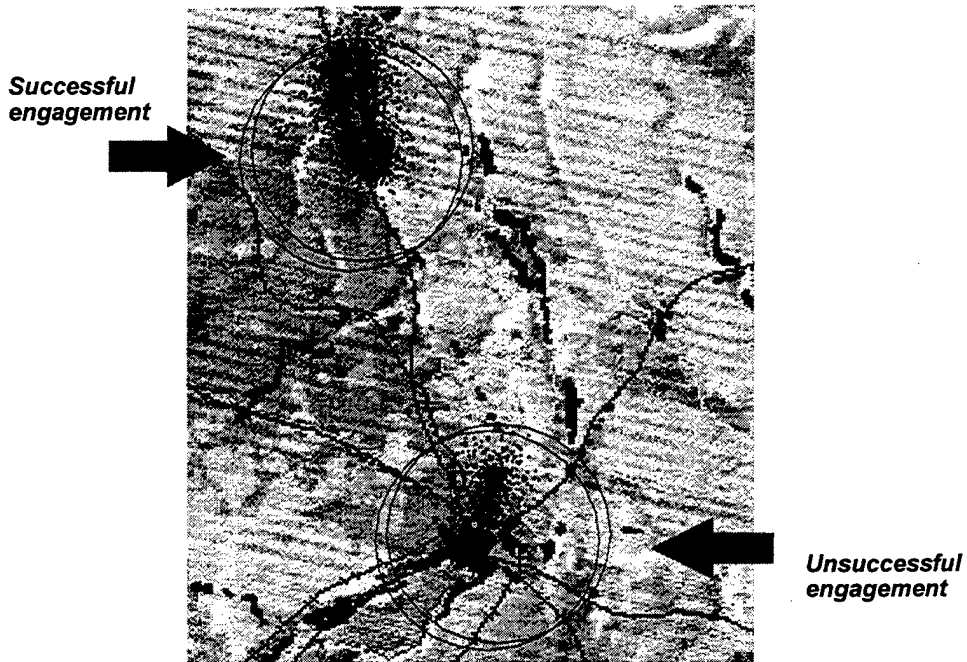
It should be noted that standoff attack might be improved with use of other tactics, such as riskier, low-altitude delivery of weapons, or use of orbiting alternative munitions. These options were not examined in this study, but they would be expected to be complicated by issues of SEAD, survivability, and deconfliction.

Reasons Why Standoff Attack Did Poorly, Even with Near Perfect RSTA & C2

- Threat is in highly dispersed formation to negate effects of massed strike (50–100 m vehicles, 1–4 km plt, 2–8 co)
- Foliage limited number of engagement opportunities
- Openings were not reattacked unless BDA indicated mission was incomplete (few dead targets in opening)
- With BDA imposed, long cycle times reduced numbers of possible engagements
- Long time of flight resulted in limited responsiveness—some targets were missed
- Submunition was not a good match for target set (sensors nonoptimal, dispersion logic imperfect)

Standoff attack did poorly in this scenario. However, it cannot be attributed to RSTA & C2 capabilities, because even in the bounding case (comprehensive information, high level of accuracy, continuous update, no time delay), an average of less than one kill per weapon was achieved. This inefficient performance could be traced to six underlying factors, several of them scenario related, such as degree of threat dispersion (ability of the threat to “reshape” itself to appear to be a less lucrative target) and level of foliage on the terrain. Many of the factors had to do with the relatively long time-to-target associated with the use of these weapons at range. Others had to do with the logic associated with multiple submunition weapon systems.

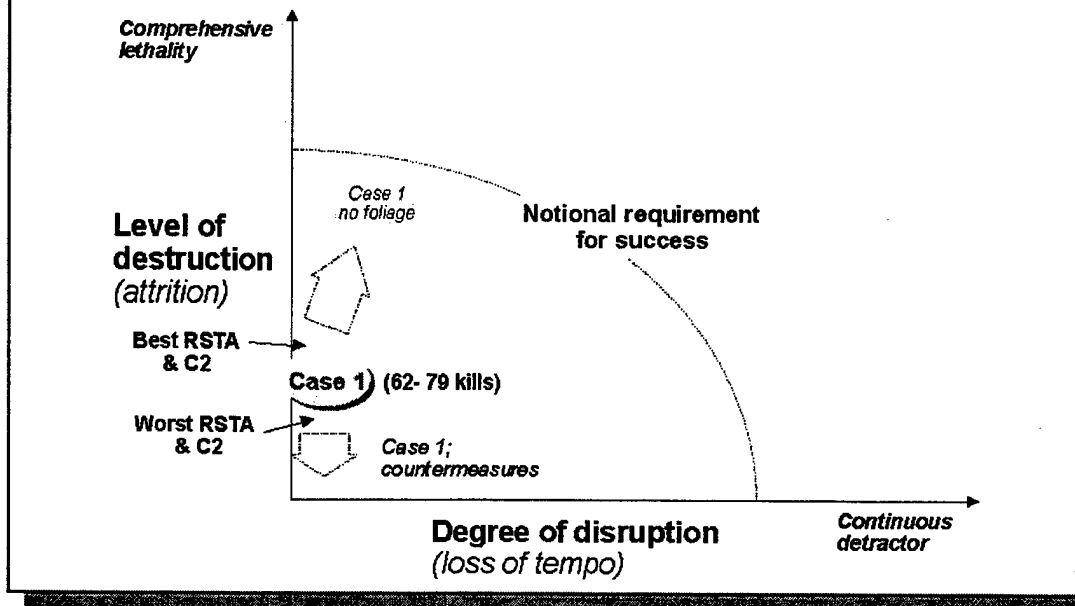
Illustration of Two TACMS Engagements



The sensitivity of TACMS to target set and environment is illustrated in the zoomed-in image shown above. At the north, TACMS is fired at a target set which is moving predictably on the road and is in a sufficiently long open area (2-3 kilometers) to guarantee encounter. The submunitions from two TACMS missiles make numerous acoustic detections, orient themselves along the column, and use their IR sensors to lock in on and kill several targets. At the south, however, two columns cross each other at a set of intersections. The forested and urban areas provide some cover, while the changing vehicle directions confuse the submunition distribution algorithm, resulting in some detections but no kills.

Altogether, Standoff Attack Operation Was Seen to Have Critical Limitations

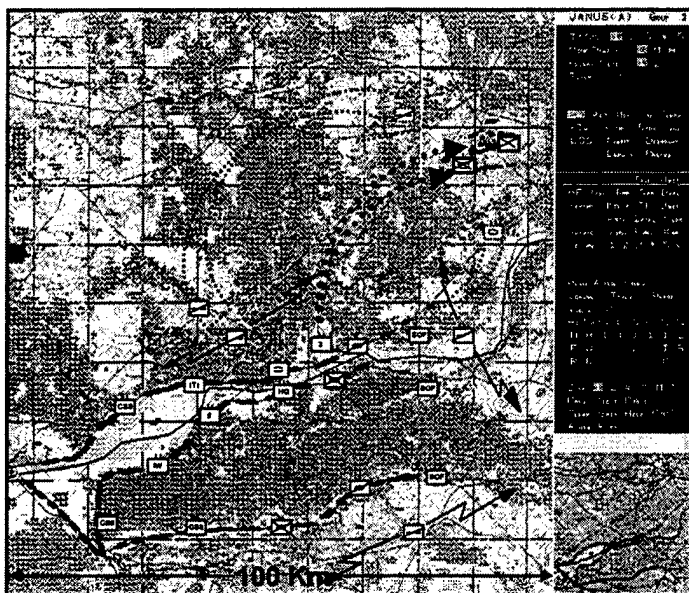
(Partly Due to Scenario/Terrain)



Plotting the outcome on the destruction/disruption axes discussed earlier, we find that standoff attack achieved a limited amount of attrition (killing 62 to 79 of the 550 enemy systems in the lead regiment). This level of attrition was found to increase strongly if foliage was omitted. We found, for example (in a separate "bald earth" run), that 195 kills were obtained. On the other hand, enemy countermeasures such as use of decoys, active protection systems, and force dispersion could reduce the kills below that achieved earlier.

In all these cases, the enemy might suffer little disruption. The standoff strikes seldom hit specific, high-value vehicles such as C2 or bridging assets, and do not have a localized "shock" effect. Rather, they attrit sporadically along the column, and the hulks would be expected to provide little obstacle to movement, particularly in this trafficable terrain. Only in the case with no cover would significant disruption be expected.

Case 2: Standoff Weapons and Airborne Ground Bn Divert Lead Enemy MRR



Observations

- Enemy commander has options: engage with artillery, engage with artillery and ground forces and bypass
- Ground force fails to accomplish assigned mission. Heavy losses are sustained.
- Blue cannot control the battlespace nor set conditions for success.
- Blue does not have the combat power (mobility nor firepower to decisively engage enemy

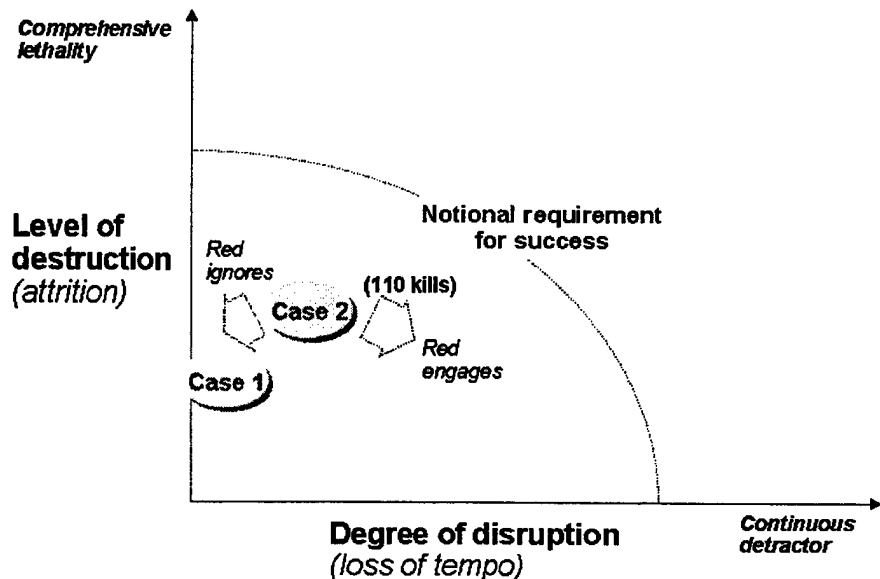
Case 2 changes the situation dramatically, but only if Red chooses to turn and attack the battalion-sized force.⁷ Even with two IRCs, the limited tactical mobility of this force renders it a relatively stationary, defense-based force. The screen shot shows the situation after the Marines have established a lodgment and secured airfields (to the north, not shown in this image), the Joint air operations have carried out SEAD on the insertion corridor, and the airborne battalion and two IRCs have been deployed to the northeast of the lead enemy regiment (shown in blue).

Once in, the U.S. force should have sufficient firepower to (1) present a serious threat to the enemy, (2) effectively engage (or at least delay) the enemy armor, and (3) successfully disengage and egress. If the force is bypassed, it does not accomplish its mission.

Assuming that the enemy turns to attack, when simulated, the results suggest that the ground force could substantially improve on the lethality obtainable by standoff fires alone. However, we note that part of the cost of this additional lethality comes in the form of losses to the ground force.

⁷ One option available to the U.S. forces might be the use of electronic warfare methods to increase the signature of this relatively small force. By doing so, the increased signature might help to force an engagement by the enemy force.

Relatively Immobile Ground Force Results in Number of Options/Outcomes to Enemy



As indicated earlier, case 2 represents a substantial improvement on case 1. In addition to increasing the lethality of the U.S. response, it also increases the force's robustness, where weapons in close proximity (e.g., direct fire) can be significantly more difficult to countermeasure. Nonetheless, we note that since this force, once in place, lacks mobility on par with the enemy, and thus it can be bypassed. Even if the enemy chooses to engage this force, depending on the circumstances, it can opt to either fight with its overwhelming numbers or break off a smaller unit to contain this force.

The map displays the Korean Peninsula with various military engagement zones and strike force enhancements. Key features include:

- Enhanced strike force:** Indicated by large, bold, curved arrows pointing towards the Korean Peninsula.
- Missile engagement zone:** A large, irregularly shaped area covering the central and southern parts of the peninsula, outlined with a thick black border.
- Aircraft engagement zone:** A smaller, irregularly shaped area located in the southern part of the peninsula, outlined with a thick black border.
- 200 Km:** A scale bar at the bottom left indicating a distance of 200 kilometers.
- Legend:** A legend on the right side of the map provides information about the symbols used, including:
 - Target:** Symbols for North Korea (NK), South Korea (SK), and the DMZ.
 - Base:** Symbols for North Korea (NK) and South Korea (SK).
 - Line:** Symbols for North Korea (NK) and South Korea (SK).
 - Area:** Symbols for North Korea (NK) and South Korea (SK).
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 - Point:** Symbols for North Korea (NK) and South Korea (SK).

- SEAD is a critical part of the attack operation
- Deploying this force can represent separate challenge
- Timely and accurate RSTA & C2 is required to create ambush situation
- Direct and indirect fires allows successful completion of mission
- Some losses are inevitable

“Reactive” Red cases must be examined

Again, SEAD is critical to the mission. Enemy air defenses endanger the aircraft lofting JSOW, the transports inserting the ground forces, and even the TACMS missiles targeting the center column. Current levels of RSTA and C2 are probably insufficient to carry out this operation. The insertion requires extensive, up-to-date knowledge of enemy strength and locations. We only instituted “moderate” and “high” levels in these runs.

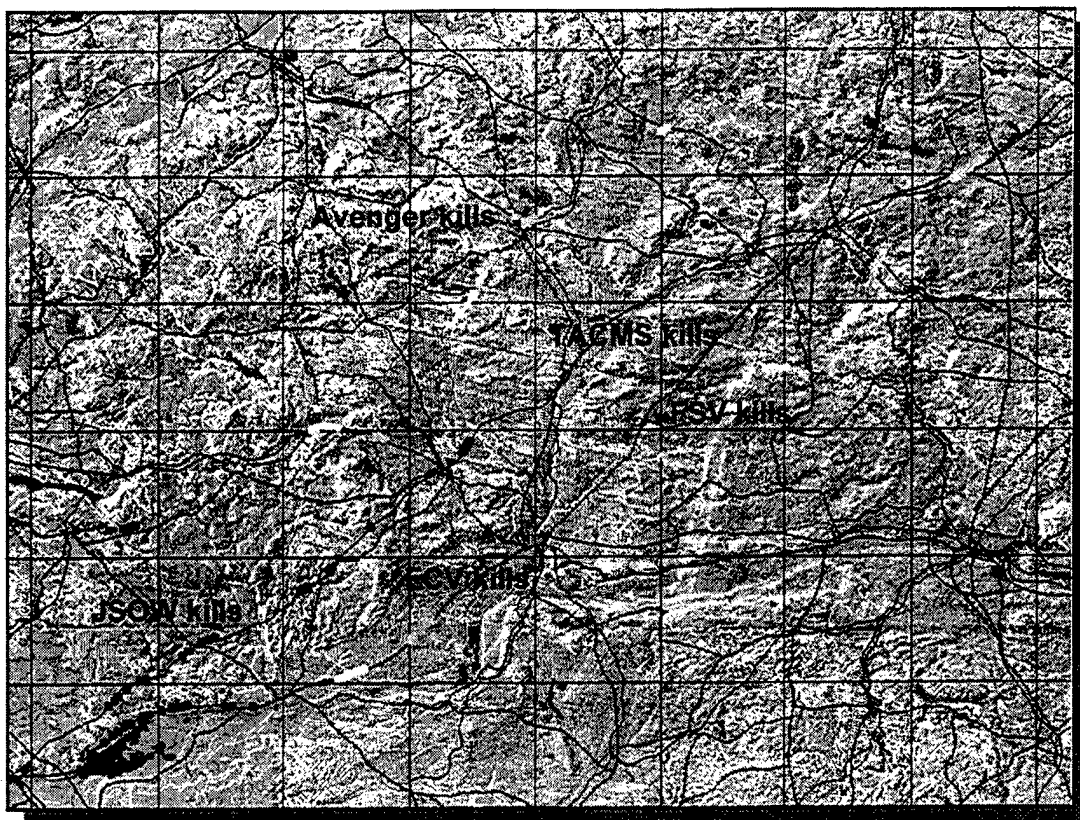
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Enhanced Strike Force (SARDA) Was Used as Representative Agile Maneuver Force

- Family of vehicles based on 20+ ton chassis; airliftable on C-130s, C-17s, and C-5s
- Selected vehicles (three of seven) from SARDA force
 - Future combat vehicle (FCV) with LOSAT
 - Fire support vehicle (FSV-2) with A-FOG
 - Future robotic vehicle (FRV); did not include weapon
- Air defense vehicle, based on Avenger, was added
- Employed in task organized teams
 - 10 teams of 14 vehicles
 - Comprised of 7 FCVs, 4 FSV-2s, 2 FRVs (and 1 AD vehicle)

Strategic mobility of this force is appears to be favorable

We opted to use a new rapidly insertable and agile force defined by SARDA for our study. It is similar in some ways to TRADOC's AAN concept and Mobile Strike Force among other novel concepts for future warfare (e.g., USMC's Hunter Warrior and DARPA's Small Unit Operations); it relies an exploitation of many technologies. Generally this concept centers on a family of roughly 20+ ton tracked and wheeled vehicles that are airliftable on C-130s. Of the seven platforms currently envisioned for this notional force, we chose a subset for use in the scenario. Each of the ten teams in our organization has seven direct fire future combat vehicles, four fire support vehicles, two robotic scouts, and one air defense vehicle. The 140 total vehicles make up two battle units, roughly a third of a full battle force.



The Enhanced Medium Weight Strike force and standoff fires resulted in a lethal combination. This image shows the distribution of kills by each type of system. Kills by air-delivered JSOW kills occur first and are shown at the lower left. Shortly after, TACMS and the FSV (firing advanced fiber optic guided missiles) produced kills in the middle and outer columns, respectively, taking out much of the armor. Avenger resulted in a few helicopter kills, and the FCV (direct-fire LOSAT) completed the destruction in a series of ambushes. All told, about half of the enemy systems were destroyed.

Emplacing This Force in Enemy Terrain Can Be a Critical Challenge—Some Options

- **Allow enemy to bypass**
 - **Must be positioned very early in timeline**
 - **Relies heavily on force's ability to go undetected**
- **Deploy from the ground**
 - **Corridor on ground must be found/created**
 - **Special refueling methods may have to be developed**
- **Deploy from the air**
 - **Successful, early SEAD campaign is required**
 - **Airfield and perimeter must be secured first**

All options require logistics plan to be reconsidered

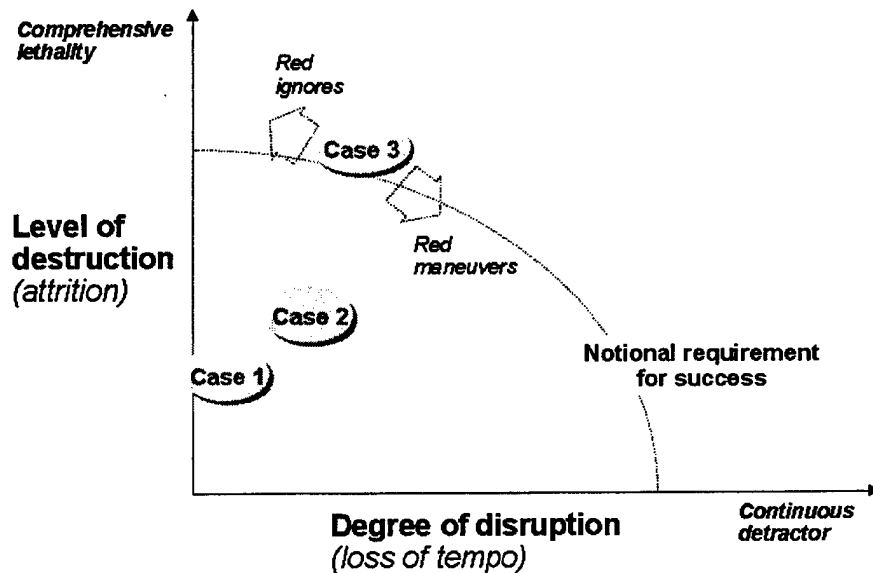
We noted earlier the difficulty of inserting a ground force deep in the enemy rear, given that Red would be expected to have a capable air defense network. Some alternatives to a direct, low-altitude insertion were also considered.

The first possibility assumes good intelligence on planned enemy movements, along with an opportunity to insert prior to the invasion. The Blue maneuver force is stealthily inserted, waits for the attack, is bypassed, and initiates the ambush.

The second, deployment from the ground, involves tactical air insertion to a region outside the enemy air defenses. Maneuver vehicles then must move quickly and stealthily to the engagement areas, and may require in-route refueling points. Refueling may perhaps be accomplished using GPS-parafoil delivered fuel bladders.

Deployment from the air, finally, may be achieved using several means. The SEAD campaign may open several corridors, or there may simply be some weak points to the enemy perimeter. A set of airfields may be secured and multiple insertion areas established. The transport aircraft flight profile may entail high altitude overflight (above the IR SAMs), followed by circling in on the landing areas. Depending on the degree of success of the air defense suppression effort, the ground force may have to be inserted against the enemy's flank and then maneuver toward the enemy. SEAD will have a large influence on how deep into the enemy array that a ground force could be inserted.

Combined Standoff Attack & Agile Maneuver Accomplishes Mission, But w/Losses



Standoff with agile maneuver, in this scenario, achieved sufficient lethality to likely stop the Red force, even if disruption were not considered. Disruption was also present because of the shock associated with the ambush,⁸ the ability of the direct fire and organic indirect fire systems to target specific high-value targets, and the presence of a capable force threatening the enemy rear that may force the opponent to change his plans.

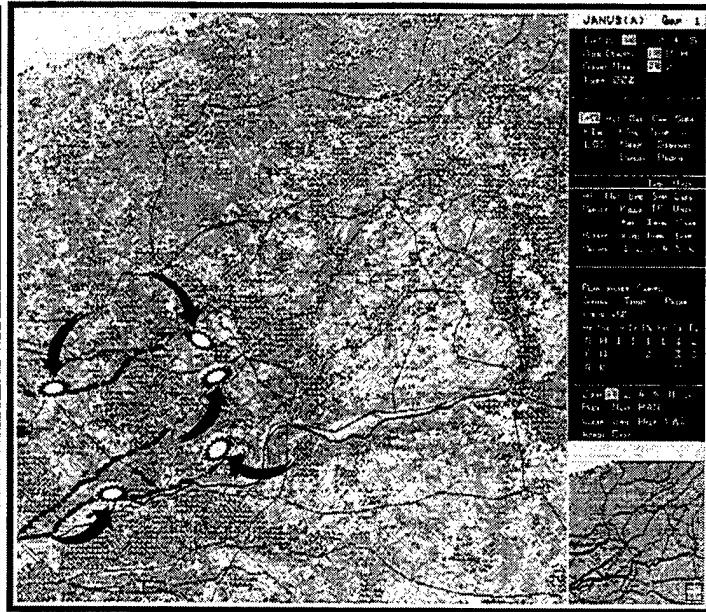
Red countermeasures will most likely reduce the impact of this force, but the effects would be limited because there are many different targeting mechanisms in case 3. These include long- and short-timeline systems, autonomous and man-in-the-loop control, seekers using different spectra, and direct fire systems able to sweep the battlefield. Standoff systems alone, on the other hand, utilize only a few different targeting modalities and thus would be expected to be more easily countered.

⁸ Once the local ambush began, a large proportion of the kills were achieved within a relatively short time, roughly 5 minutes.

Case 4: Attack Can Be Focused on Support Entities Provided Enough Information Exists

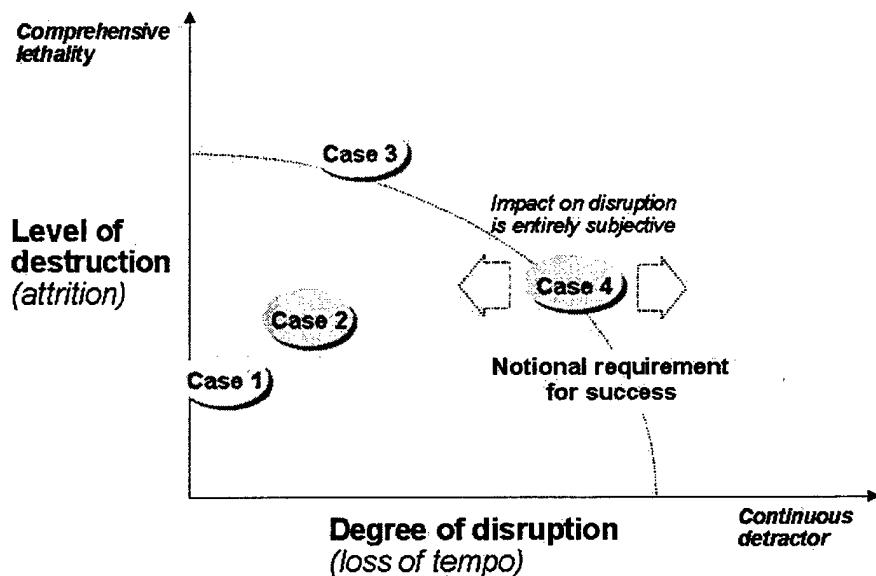
Possible issues

- How much information is needed to execute this kind of mission?
- Does attacking support vehicles have direct enough impact on enemy capability?
- How much agility is necessary for this force to successfully extricate?



One shortcoming of the agile maneuver force is its vulnerability to massed direct fires. This may be avoided by attacking less dangerous elements such as resupply vehicles, C2 centers, AD sites, assembly areas, and artillery units. These should have a major impact on the enemy advance yet result in few U.S. losses, provided the agile maneuver units can extricate quickly after the attack. Preliminary runs with such a maneuver showed an order of magnitude fewer losses than when attacking similar-sized armor units.

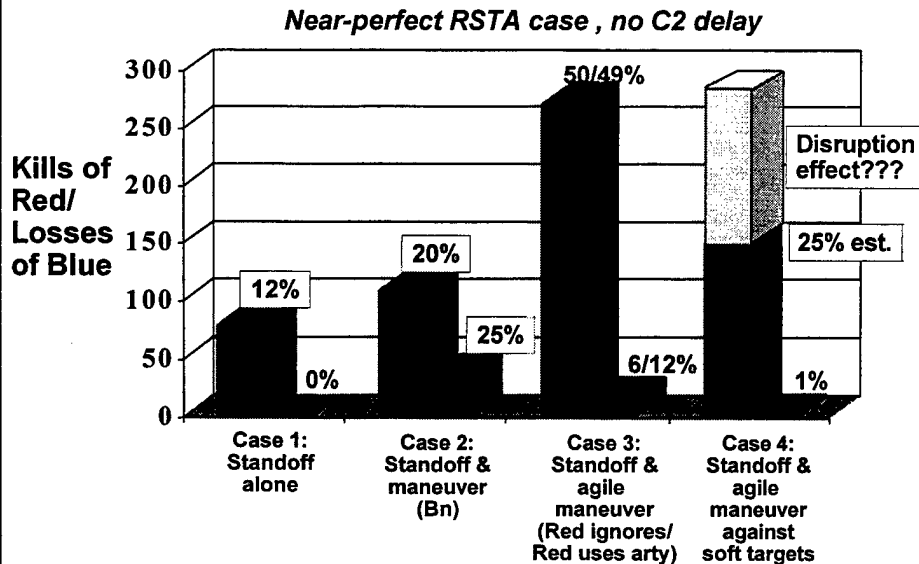
Combined Standoff Attack & Agile Maneuver Against Soft Targets Achieves Objective



Since the agile ground forces were competing with long-range standoff fires for the same more-lucrative logistics and supply vehicles (CS targets), overall lethality was not as high as seen in case 3. However, we note that because there was considerably more focused lethality on a specific target set, where all of the additional kills were directed against the soft logistics and supply vehicles, the effect of disruption would be significantly, perhaps exponentially, higher.⁹ How much higher, remains to be quantified. (To some extent, this may reinforce the notion that simulation tools, including the ones used here, tend to focus on attrition effects, which tend to be much more measurable. Other effects such as reduction in morale due to significant losses in short periods of time, for example, tend to be unaccounted for.)

⁹ The additional kills were contained to the same target. Enemy CS losses were roughly 8% for case 1; for case 4, losses of CS were roughly 30%.

Standoff Attack with Maneuver Dramatically Increases Lethality (with Some Losses)



In summary, we note that case 1, which involved the aggressive use of standoff fires, resulted in a respectable 12% attrition against the overall enemy force. One advantage of this concept was that because direct exposure to the enemy was minimal, no losses occurred—assuming high-altitude JSEAD was successful. Case 2, which involved both standoff fires and what might be considered a conventional ground force insertion, provided increased lethality (and robustness), but at the cost of considerable losses to the U.S. force.

Case 3 represented a substantial increase in lethality from cases 1 and 2. The two variations of case 3 show different enemy reaction to the concept. If Red ignores the ambush and presses on, about 6% of the Blue force is lost, primarily direct fire FSVs. If Red reacts to the initial ambushes by stopping (resulting in significant delay) and directing fire support missions into ambush locations, U.S. losses increase. Organic direct and indirect fires each contributed as many kills as standoff fires. In fact, due to the shock of the ambush, enemy losses of less than 50% may well be sufficient to disrupt the enemy march. If so, fewer direct fire ambushes may need to be triggered, reducing U.S. losses further.

Case 4 represents a significant departure from the way we think about assessing force effectiveness. Rather than a force-on-force engagement analysis, this tends to be a force effects analysis where most of the effects may be non-attrition-based. Thus, to some extent we've only begun to characterize the effects of this concept.

Outline

- **Scenario**
- **Approach**
- **Results**
- **Insights**

This final section describes general insights coming out of the analysis.

Insights from Research (RAND Scenario)

- **Combination of engagement and maneuver capabilities is required for joint force robustness**
 - **Standoff engagement offers tremendous potential to shape battle conditions, but comes with key physical limitations**
 - **Agile maneuver allows control of terrain and enemy action, but comes with inherent risk**
- **New RSTA and C2 capabilities can enable some concepts; for others, it will not be the critical factor**
- **New strategic and operational mobility capabilities, to some extent, may be able to offset each other**
- **Lighter ground force systems may be required for agile maneuver (quick-reaction) missions**
- **Weapons may be limiting factor for standoff engagement**

We were surprised to find that standoff attack using long-range ground, Naval, and air-delivered weapons had limited effect. Weapons were seen to be poorly matched to the targeting opportunities that presented in this mixed terrain. Even near-perfect levels of RSTA & C2 could not overcome the combination of long weapon flyout times and short enemy exposure opportunities.

Ground forces, on the other hand, were more responsive and selective in their fires. In combination with standoff weapons, they were able to decisively defeat the enemy force. Overall, it appears that a combined fires and maneuver attack against the enemy had much greater effect than fires alone. The enemy commander would have been presented with a multi-faceted threat via this approach. Of course, this comes at a cost. Some of the agile maneuver vehicles were lost to enemy fires, and the insertion itself may be extremely difficult.

We were also surprised to find that improved RSTA & C2 were far more important to ground force operations than for standoff attack, the opposite of what one might expect. Comprehensive, up-to-date information was perceived as a requisite for the insertion, setting up the ambush, targeting local indirect fires to isolate the ambush, and disengaging and egressing from the area. Much less information was necessary to target large-footprint standoff weapons.

A key decision is how much of the fight should be assigned to the different weapon systems. The long-range fires were effective only in open areas against sizable units. The local indirect fire units were lethal, but they had limited resupply. The direct fire systems were selective, but they open themselves up to return fire if gaps are not provided by the other weapons.

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MODELING, SIMULATION AND ANALYSIS AS CRITICAL CAPABILITIES³⁹

Model-supported analysis is a critical enabler for progress on initiatives suggested in the 1998 DSB summer study. Unfortunately, it is not currently up to the task. This paper reviews the issues and notes developments that could greatly improve DoD's transformation-related analysis and experimentation. It also suggests investments and changes to DoD's "operational doctrine" for analysis.

ON THE ROLE OF MODELING, SIMULATION, AND ANALYSIS

In the Process of Transforming the Force

The 1998 DSB Summer Study sought to identify concepts, technology, and methods for pursuing the broad ideas sketched in Joint Vision 2010. One element of this work was identifying enablers of progress. Analysis, supported by modeling and simulation (M&S), is such a capability. One way to appreciate this is to consider an idealized process of moving from broad visions, such as those the DSB has identified, to concrete choices, decisions, and actual changes of force and doctrine. Such a process might be:

- Identify key operational challenges and subchallenges
- For each subchallenge, develop alternative operational concepts that exploit U.S. strengths, including new technology.
- Assess alternatives through analysis and experimentation.
- After refining the alternatives, pursue the most promising ones experimentally. Observe, analyze, and iterate.
- As knowledge accumulates, commit to investments and changes in force structure and doctrine.

Figure 1 illustrates an operational challenge (an early counteroffensive) consistent with JV 2010's emphasis on dominant maneuver and key ideas developed in the 1998 DSB summer study. The idea here is that, given sufficient information superiority and other enablers, U.S. forces—even those able to deploy with days and weeks rather than months—should be able to roll directly into offensive operations rather than plan a multi-month sequence of halt, build-and-pound, and eventual massive counteroffensive. As Figure 1 suggests with its decomposition, however, an early counteroffensive would depend on a number of subordinate joint challenges, success with which would depend on crosscutting functions such as precision fires and information superiority.

³⁹ Written by Paul K. Davis

Let us now suppose that this challenge is to be studied in depth with a variety of operational concepts for accomplishing the missions. As Figure 2 suggests, carrying out such a study will typically lead to a construct in which M&S-supported analysis is ubiquitous. M&S are essential in designing research (including major experiments), in conducting the experiments (since only some features of the operation are likely to be tested “live”), and in analyzing results. Further, since the experiments can cover only a small portion of the scenario space, it is necessary to depend ultimately on analysis in judging the worth of alternative concepts and the realm of their applicability. That is, M&S-supported analysis is fundamental to the process, not merely one of many components. This has long been recognized in many domains and there is a name for the relevant process, “Model-Test-Model,” which is intended to emphasize that one starts with a model—however imperfect—conducts research, refines the model(s), and so on, iteratively. The experiments seldom provide decisive information adequate for decision making, but they help shape and calibrate the knowledge base—much of it in the form of models—so that reasoned decisions can in fact be made. By referring to *families* of models, Figure 2 reminds us that what is needed is not a single “right” model, but rather families of models with different levels of resolution, different perspectives, and purposes.

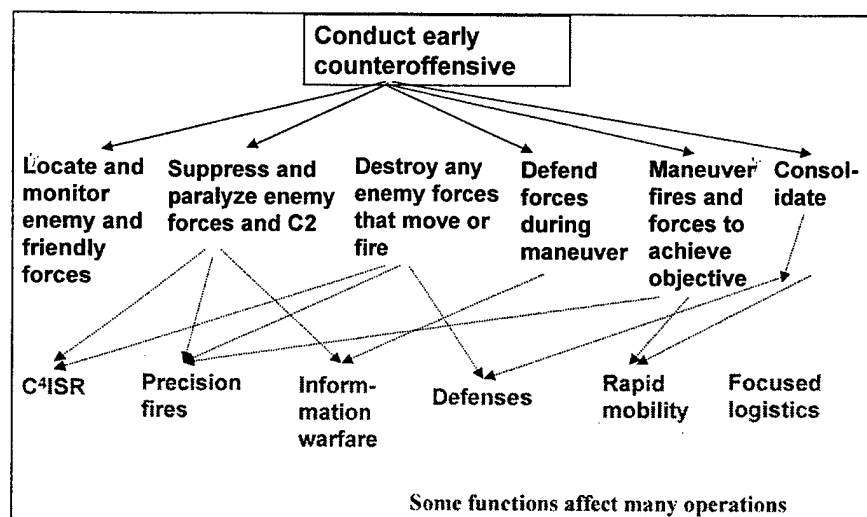


Figure 1—An Illustrative Joint Operational Challenge and Its Decomposition

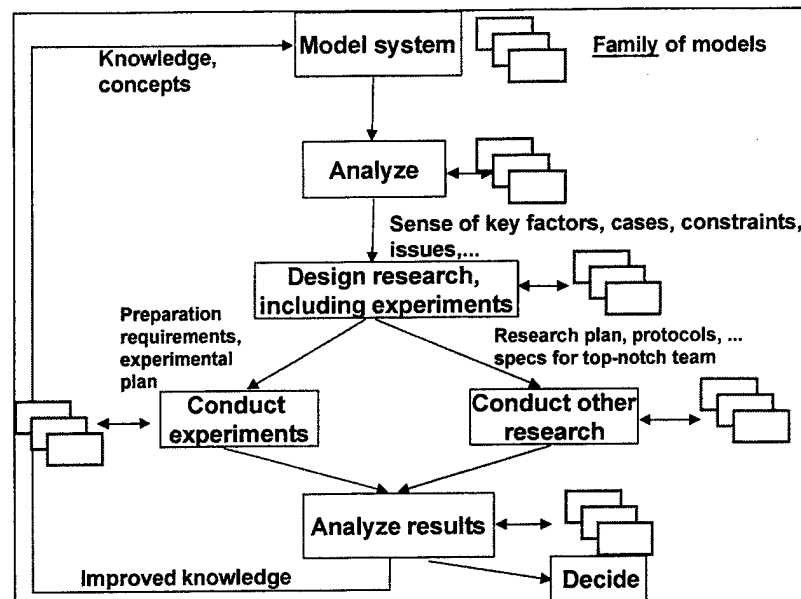


Figure 2—The “Model-Test-Model” Approach to Advanced Concepts

In Future Command and Control

It is one thing to use M&S-supported analysis for peacetime activities such as defining and choosing among alternative programs, or assisting the transformation process generally. It is quite another to use it in war. Even the notion of doing so may seem strange to many. Although models have long been used for war planning, they have typically been most useful for specialized purposes such as estimating logistical demands or deconflicting air sorties, rather than predicting the dynamics of battle. However, the images of future operations in JV 2010 call for highly parallel, time-compressed multi-component operations that could not possibly be fully rehearsed “live” and that could not possibly be planned and executed well without extensive modeling and simulation. Further, the feasibility of rapid adaptation during operations will depend on having previously “played through” a range of cases, and in some cases on being able to generate and evaluate alternative courses of action quickly. All of this is sometimes recognized by those who say that modeling and simulation is becoming increasingly embedded in the command and control systems—to such an extent that sometimes one is hard put to distinguish what is real and what is being modeled. This is explicitly desirable in peacetime exercising, of course, since one wants the sensors and command-control system to “see” and react to many enemy actions that cannot be duplicated live.

ENABLING SCIENCE AND TECHNOLOGY FOR M&S

If one accepts the importance and ubiquity of analysis, modeling and simulation, what are some of the technological aspects that make it more productive and potentially capable than in the past? This is important because it is generally agreed that current M&S-supported analysis is not up to the tasks ahead. Changes are essential.

1. Advanced Distributed Simulation (ADS or DIS)

Distributed simulation is now a reality as the result of two decades' of investment. It is widely used for training and certain demonstration experiments. It is a core technology for joint warfighting experiments. One of its key features is that it allows specialist groups—within or across Services—to work together in integrated activities using a combination of constructive models and man-in-the-loop simulations. This is especially powerful when dealing with new operational concepts because constructive models are seldom able to represent innovative concepts well. Instead, gaming is needed to define those concepts, after which they can in some cases be represented in constructive models. Also, live testing can be incorporated where it is most needed (e.g., in learning experimentally what is feasible for real-time command and control and fusion of RSTA information). Figure 3 illustrates a concept of using advanced distributed simulation (referred to in the figure by the acronym DIS) in conjunction with war gaming, modeling, and analysis. As noted earlier, major experiments are only one portion of the overall effort.

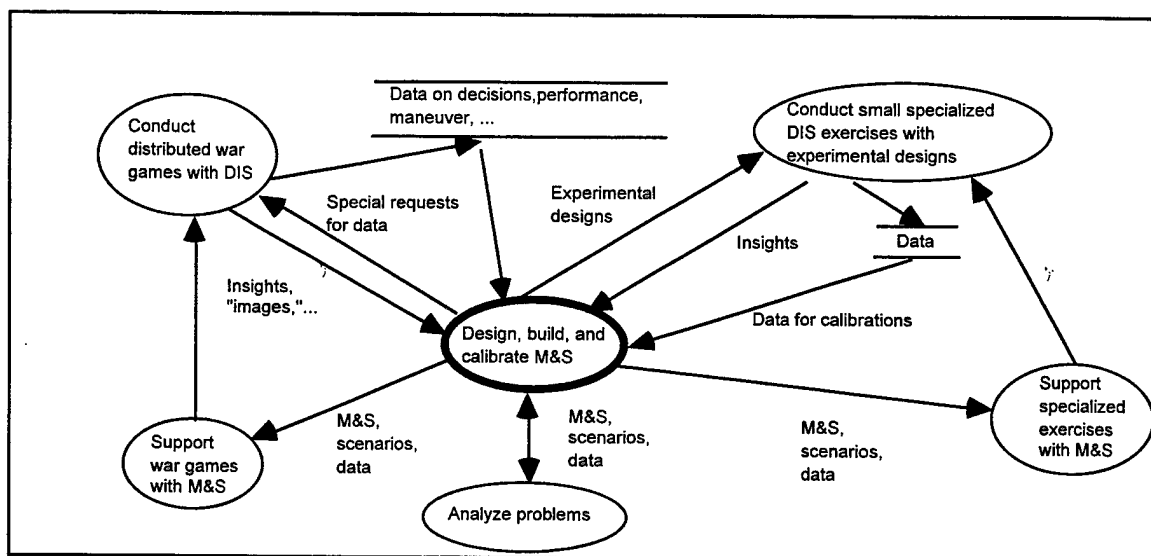


Figure 3—Advanced Distributed Simulation as Part of Broader Research

2. Relatively Broad-Scope Entity-Level Simulation

Another enabling technology, one due to progress in both computing power and programming methods, is that allowing us to simulate activities at the level of the individual tank, aircraft, or even infantry soldier. Sometimes this can be uniquely valuable in clarifying the relevant phenomenology or in giving users an intuitive sense for the operations and the interrelationships among components. Even within the current DSB summer study such simulation generated distinctly nonintuitive results regarding combat in mixed terrain, which reinforced emphasis on combined use of long-range precision fires and maneuver forces, rather than the former alone. In the predecessor DSB study in 1996, such simulation dramatized the risks associated with placing small ground-force teams far forward with nothing but long-range fires to protect them. This entity-level work highlighted the value of providing such teams with

some organic capabilities to deal with enemy "leakers." Such work is most successful when it includes a mixture of gaming and closed simulation.

3. Modeling of Decision Making and Behaviors

Most high-resolution, entity-level work focuses on physical processes such as attrition. As a result, it can be valuable for assessing lethality and survivability, and for understanding effects of terrain and weapon characteristics, but it is often much less useful in understanding strategy, higher-level tactics, and the likely real-world unfolding of battle. Fortunately, newer simulation methods have the potential to represent human decision making and behavior. These methods are still in their infancy but it is possible to do much better than to continue using "scripted" models.⁴⁰

A diversity of decision making and behavioral models is needed. For example, it is useful to have simulation versions of game-theoretic models that indicate what the smartest strategy would be if both sides had perfect situational information. With such models one can also infer "optimal" decisions for cases with an asymmetry of information. Such models depend, of course, on the sides' assumed objectives and risk aversion. Since no commander has complete information, the value of such models is in generating insights and intuition rather than truly optimal strategies. A different class of models is less algorithmic in flavor and more dependent on methods associated with computer science, artificial intelligence and complex adaptive systems. These range from search methods such as genetic algorithms to models of decision making that exploit so-called production rules, scripts, and much more sophisticated hybrids. Perhaps the most important class involves so-called "agent-based modeling." Such modeling can represent the *results* of rational but heuristic reasoning of the form exhibited by humans. For example, it may represent war plans with preplanned contingent options and a set of partially defined response actions to unscheduled events that may occur at any time. Or it may represent doctrinal behaviors in a rule-based framework. Although the terminology of "agent-based modeling" may seem esoteric, it often amounts simply to including explicit models of decision making. Such models act in behalf of humans (hence the name "agent")—taking contingent actions, changing plan, etc. This can have a profound effect on the way the simulation then unfolds. What is perhaps most remarkable is that so few current DoD models are "agent based," since it has long been known that strategy and tactics often dominate results. Agent-based techniques could also be used to assist exploratory analysis and even to help infer useful aggregate-level models from more detailed simulation experiments.

With both kinds of modeling—algorithmic or more Alish—it is possible to have alternative versions that represent different decision makers—either generically (e.g., risk-averse or risk-taking) or, to some extent, in ways idiosyncratic of individual commanders. This is important because real-world decisions reflect a mixture of situation, doctrine, and individual-commander style and psychology.

⁴⁰ For citations to relevant work see bibliography, especially NRC (1997). The base of relevant experience here includes work by the Santa Fe Institute, RAND (RSAS, SAGE, COF), Los Alamos National Laboratory (TRANSIM, EAGLE), and CNA (ISAAC).

By no means is it easy to develop useful decision models. Further, they are often best developed in an iterative process that includes human gaming in which the commanders are encouraged to go beyond doctrine and conceive unusual strategies and tactics. Once identified, these can usually be represented. In some cases, neural-net and genetic-algorithm methods have also proven useful in identifying unusual but good strategies.

In summary, there are a number of new methods, most notably agent-based modeling that can be brought to bear in modeling human decision making and behavior. So long as the emphasis is on understanding possibilities and patterns, rather than on predicting actual behaviors with certainty and precision, these can be quite valuable in both analysis and M&S-supported experiments. Even imperfect decision models can be a great improvement over experiments that assume a stupid or fully predictable adversary. Although applications are still fairly primitive and some efforts have been unimpressive, these methods for modeling decision making are an important enabling technology. Table 1 suggests some of the many issues that can be represented. The point is not to contrast ORish and AIish methods, but rather to note that many decision issues could in fact be modeled with available technology.

Table 1—Modeling of Decision Making

<i>Issue to be Modeled</i>	"A.I" Methods, Agent-Based Modeling, Neural Nets,...	More ORish Methods
Unimaginative attrition battle (e.g., standard piston models)		Scripts and simple rules such as: attacker reinforces success and defender reinforces failure
Preplanned contingent maneuvers and other actions at operational level (e.g., concentration and counterconcentration, choice of paths,...)	Branches in rule-based "war plans" within simulations	
Unscheduled adaptations (e.g., reaction to chemical use or surprise failure of a sector)	Continuous event-checking to trigger changes of plan or special suboperations	
Difficult battery-level decisions with time pressures and multiple inputs of data	Fuzzy-logic rules	Decision-analysis algorithms incorporating fusion methods and weighting uncertainties differently by situation
Doctrinal allocation of sorties across target classes	Rule-based "war plans"	Simple algorithms
Game-theoretic daily "optimal" allocation of sorties accounting for enemy's most effective or most likely behavior		Game-structured simulation algorithms incorporating mathematical programming
Massing of fires and forces for offensive ground action	Rule-based decision models incorporating same content as Soviet Correlation of Forces methodology	Soviet Correlation-of-Forces methodology
Tactical decision rules for ground forces	Neural-net methods, decision tables, ...	Decision-analysis tables
Reasonable behaviors at the tactical and engagement levels	Rule-based methods as in SAFOR or "subjective transfer" models based on structured interviews of operators	Algorithmic behaviors, as in Brawler (an air-to-air engagement model)
Different possible behaviors as function of enemy commander's "style"	Alternative branches war plans and alternative "play the board" models	Different parameter values in algorithms to reflect, e.g., different utilities and degrees of risk aversion

4. Theory and Methods for Creating Multiresolution Families of Models

Another new development is a better understanding of what is needed to generate and maintain sensible families of models that differ in resolution, representation, scope, and other attributes, but that can be used jointly for analysis superior to that likely with any single model. Although families of models have been attempted for decades, the track record has not typically been good. The reasons have included: (1) organizational difficulties, (2) the absence of realistic high-resolution models, (3) poorly conceived aggregate models, (4) limited computing power, (5) culture gaps between those who prefer to work at high and low resolution, and (6) lack of

adequate scientific rigor. On the latter, for example, a high resolution model is sometimes used to calibrate a lower-resolution model by using an allegedly representative high-resolution case, without paying attention to the probability distribution of behavior and outcomes at that level. Also, calibrations often implicitly assume that lower-level phenomena are “equilibrated” (e.g., as when it is assumed that a defending ground commander uses his reserves so well that breakthroughs are avoided and outcomes depend only on force ratios). Such practices severely undercut the value of model families. In any case, although in recent years the DoD has done little to encourage model families, there is more interest in doing so now and much could be accomplished. Good work in this domain requires strong designs, first-rate talent, and an emphasis on good military science rather than viewgraphs.

Within the current DSB summer study an ad hoc family of models was used experimentally to examine the so-called halt problem in mixed terrain. Even though these models were by no means integrated, the results illustrated powerfully the value of viewing problems from different perspectives and at different resolutions (see discussion of analysis in Volume 2).

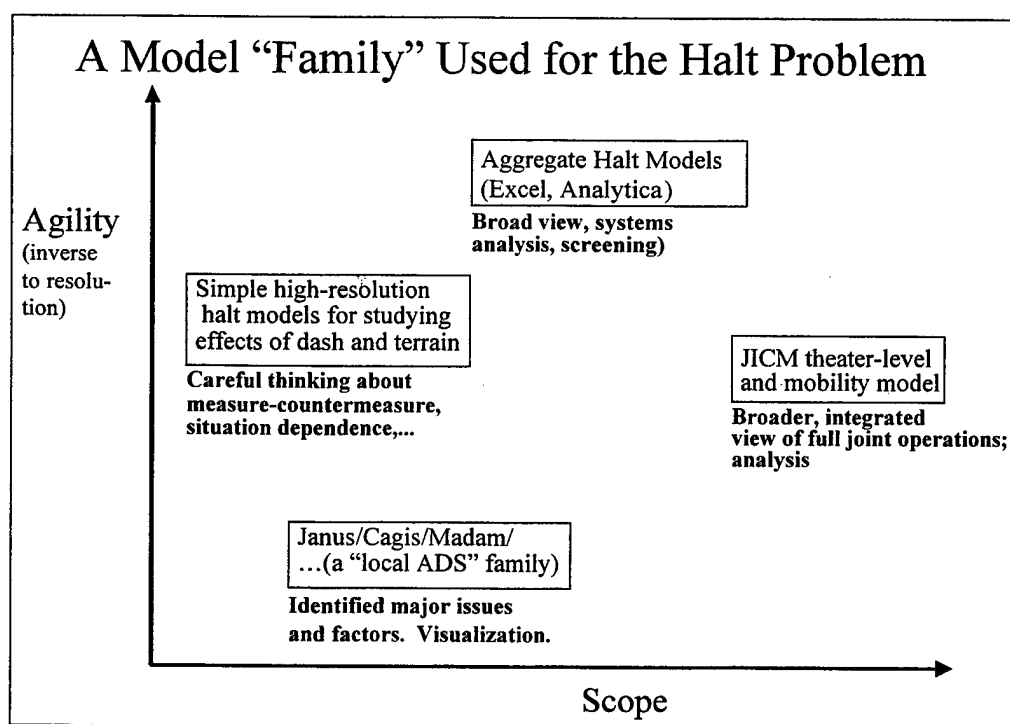


Figure 4—An Ad Hoc Model “Family”

5. New Desktop Analytical Tools

Within recent years a number of analytical tools have emerged that greatly expand what high-quality analysts can do, even at the desktop. In particular, there are powerful tools for simulation (e.g., iThink, MODSIM, VSE), decision making under uncertainty (e.g., Analytica and Crystal Ball), and analytical closed-form problem solving (e.g., Mathematica, Maple). These make it possible to do broad-reaching exploratory analysis with models that are far more comprehensible

than traditional models. This is in addition to the ubiquitous spreadsheet programs such as EXCEL and increasingly powerful simulation languages (C, C++, SmallTalk, ModSIM,...)

6. Query and Explanation Features

If challenged to do so, the software technology community can provide substantial “explanation” capability for M&S—at least to the extent of providing well structured audits of logic for model decisions, quickly understandable data bases, and query capability. It is a more fundamental problem to provide deeper “explanations,” but even the first-order versions are far superior to what is provided with traditional models. Unfortunately, query-and-explanation features have not been emphasized in recent commercial developments, or in DoD-supported research. To some extent, most of the commercial products available are worse in this regard than experimental languages used a decade ago. However, this can change with priorities. It needs to change if M&S is to play a pivotal role in command and control: commanders must be able to understand the basis of their decisions.

CURRENT STATUS

An Inadequate Base of Military Science

Although analysis supported by M&S will be fundamental to the success of efforts to transform the force, current analysis and M&S tools are inadequate—especially for higher-level functions such as that of interest in joint work. The relevant models are often quite far from “the physics,” which can sometimes be simulated with good accuracy, and must instead reflect many “soft” factors such as competing strategies, adaptations, and frictions. “Prediction” is a chimera here and exploratory analysis across vastly different scenarios and situational details is much more appropriate.

This said, a great deal could be accomplished if the base of knowledge were greater. To put it differently, the biggest problem is less model *software* than knowing what knowledge to embed in that software. We know a great deal about large-scale combat of the WW II variety, but much less about future warfare involving highly parallel operations in compressed time periods with high-lethality weapons and networked systems. By far the majority of current work seems to be at the viewgraph level, which at best uses nominal planning factors and at worst uses factors with no empirical basis whatsoever. The reality of such operations would almost surely be very complex technically and mathematically.

Problems with DoD's Analytical Culture

The analytical baseline is also troublesome for reasons identified in the 1996 DSB summer study (Volume 2, report of the analysis panel) and in subsequent studies. Over the last decade, the DoD seems to have become increasingly wedded to consensus and buy-in, which are usually laudable, but which can be counterproductive when the purpose is objective, insightful and non-

standard analysis across a wide landscape of cases. The DoD has also emphasized standardization to such an extent that one senior official was quoted as saying, "If you're not part of the JWARS or JSIMS effort, why do you exist?" And, to make it worse, the DoD's approach to model building has sometimes been quite centralized in government, noncompetitive, and bureaucratic. Although standard data bases and cases are surely useful and even necessary as baseline points of comparison, there should be far more emphasis on competitive and deliberately redundant approaches, a multiplicity of models, off-design work, and open discussion and sharing of models components. This could be made much easier by recent progress in the high level architecture (HLA). The objective should be a marketplace of analysis and M&S, which are reusable (at least with only moderate recoding), not predictable "standard" results and tidiness.

Strengths and Weaknesses of Current Models, Simulations, and Analysis

Substantively, current higher-level DoD models and simulations have many well-known limitations. Many betray their cold-war origin and emphasize relatively mindless attrition rather than maneuver of fires and forces, networking, adaptation, or even strategy. The biggest single problem with current analysis of future-warfare concepts is probably the impoverished representation of command and control, RSTA, and decision making. Related to this is the failure adequately to address the central issues of risk and uncertainty, which become especially important when considering future operations. Indeed, the so-called "expected outcome" of deterministic simulations should be of relatively little interest. Instead, the focus should be on assuring high-confidence operational success despite a myriad of uncertainties.

RECOMMENDATIONS

We have the following recommendations:

- The DoD and Services should increasingly focus analysis of future operational concepts on assuring high-confidence success (i.e., on risk reduction). Analysis should consider a wide range of scenarios and operational circumstances (scenario-space analysis) and should apply modern methods for characterizing uncertainty to identify potential difficulties that can then be addressed and mitigated. This will require sophisticated treatment of probability issues, including the treatment of probabilistic dependencies (correlations).

WHO: USDA, DPA&E and VCJCS. **HOW:** Through demands expressed in the PPBS system and other forums.

- The DoD and Services should create research and analysis programs for each major new warfare area (e.g., precision fires), assuring development of a solid base of military science. Such research and analysis should be attached to warfare programs, rather than be buried as fundamental research: assuring close working relations between innovative operators and analysts is critical.

WHO: DDR&E , VCJCS. **HOW:** investment mandated from the top after review of current programs.

- The DoD and Services should assure existence or development, for each major warfare area, of an appropriate family of models. Over time, many of these should be related through integrated multiresolution designs. The purpose should not be standardization, but rather facilitating insightful analysis across a wide range of assumptions.

WHO: DDR&E/DMSO, with help from DARPA, JCS (J-8), and PA&E.

HOW: broad requirements and investment, plus fostering of relevant scientific exchanges and publications.

- The DoD should shift the style of its approach to M&S so as to emphasize a marketplace of competitive ideas, models, and analysis. It should distinguish sharply between (1) technologies and standards that can promote open-market operations such as the exchange and reuse of model components and (2) the understandable but wrongheaded desire by some officials and officers for extreme model and data-base standardization.

WHO: USD(A&T), DDR&E, DPA&E, DARPA. **HOW:** (1) Add substantive research components to activities such as the JWARS program; (2) give DMSO a charter for encouraging and even supporting research on advanced M&S methods and theories; (3) review the JWARS and JSIMS programs to assess progress on issues such as modeling decision making and behavior, families of models, and treatment of risk and uncertainty; and (4) in all of these, assure support for a diversity of ideas and researchers.

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The material in this paper was adapted from a variety of sources, which in turn include extensive citations to the literature:

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Modeling, Simulation, and Analysis Will Be Central, But Research Base Is Lacking

Description and Rationale

- o Will be **principal** basis for assessing new op concepts:
 - Joint experiments are critical but have very limited role
- o M&S will be embedded in future JTF C2 and critical to adaptive planning

Program/Force Implications

- o Warfare-area research and analysis programs
- o New investments in integrated model **families** (varied resolution, scope, perspective; interactive and closed analysis...)
- o MOEs addressing operational uncertainties and risks
- o Related changes in PPBS

Enabling Science and Technology

- o Advanced distributed simulation (ADS, DIS)
- o Entity-level simulation
- o "Agent based modeling"
- o Desktop analytical tools
- o Mil. science of future warfare, including complexity and adaptation
- o Theory for integrated model families
- o Models of decision and behavior
- o Query and explain features

Problems and Uncertainties

- o Poor current science base for future ops, poor understanding of risk and uncertainty, poor current models, and current programs
- o Questions about suitability for these purposes of JWARs and JSIMS
- o DoD's ability to change analytical culture (less consensus, more innovation, empiricism and exploration of "scenario space")